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Department of Industrial Engineering and Management Sciences
The Technological Institute
Northwestern University
Evanston, Illinois

AN ANALYSIS OF SELECTED STRATEGIES FOR ORGANIZING R & D IN DEVELOPING COUNTRIES WITH REFERENCE TO POLICY AND PLANNING TECHNIQUES, INTERNATIONAL RELATIONS MANPOWER AND TRAINING, AND INFORMATION REQUIREMENTS

Earl C. Young

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ABSTRACT

This thesis is an exploration of the set of problems confronting the developing countries in their attempts to build a scientific and technological capability. The analysis is made in terms of a general flow model similar to the one used in the Program of Research on the Management of Research at Northwestern University. The major topics explored include science policy, research planning in relation to economic planning, international scientific relations, manpower and training problems, and the flow of scientific information.

Scientific objectives collected from policy statements have been classified to determine the nature of scientific goals in these countries. Strategies at the international, regional, and national level have been identified in order to determine the means used to obtain these goals and to describe selected R & D patterns which appear to be emerging. Finally, several statements that can be operationalized as testable propositions have been collected and classified. Major trends noted and analyzed include the major role played by the national government in establishing and controlling scientific activities, the growing importance of international relations, the widespread and strong orientation to economic development projects, and the almost universal desire to establish an indigenous scientific capability.

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I. INTRODUCTION

I.1 The Study and Its Relationship to the Overall Study

A long range study of the Organization of Applied Scientific Research (Research and Development of "R & D") in developing countries is being conducted under the direction of Professor Albert H. Rubenstein of the Department of Industrial Engineering and Management Sciences of Northwestern University. The continual upgrading of aspirations and the increasingly ambitious development plans of the emerging nations are believed by many to be increasingly dependent on science and technology. At the same time those responsible for the establishment, maintenance, and expansion of R & D activities in developing countries are confronted with numerous constraints and difficulties which impede their progress. As a consequence, numerous strategies are evolving to achieve the desired scientific objectives, but each is modified by particular local circumstances.

Accordingly, this long range study at Northwestern University has developed in two concurrent phases. The first is the general analysis and comparison of the alternative means or strategies proposed or now in effect for establishing R & D capabilities in developing countries in the physical sciences and selected natural sciences, other than medicine. The second is a series of analyses of the current facilities for scientific research in several areas including Latin America, Asia, and Africa. Regarding the first, a preliminary analysis of some of these alternative strategies was made by A. H. Rubenstein and E. Young[1]; regarding the second, two master's theses have been completed, one on Latin America by Mario Pantin,[2] and one on South and Southeast Asia by Pakhorn Adulban.[3] Also in relation to the second topic, a preliminary attempt to describe R & D patterns based on currently identified strategies was made by A. H. Rubenstein and E. Young.[4]

This thesis will continue the study in both of these areas. In addition, it is apparent that certain problems and developments in establishing these facilities are receiving the greatest attention, i.e., international scientific relations, manpower, information services, and funding. In short, R & D patterns in developing countries, although unique in every case, are emerging with certain characteristics in common, and an understanding of these developments is essential to an examination of alternative strategies. Consequently, this thesis begins with an examination of the characteristics of R & D patterns in developing countries, and then moves to an analysis of alternative strategies expanded in terms of these characteristics. At the same time, an attempt will be made to examine the scientific objectives which determine these strategies. Finally, since additional data is now available from all major developing areas, a further refinement of country R & D patterns will be made.

I.2 The Objectives of the Study

The three sections of the thesis referred to in the preceding paragraph point up the general objectives of this study. First, it is a further definition of the main parameters of R & D patterns in developing countries. Secondly, it is a study of the alternative strategies for applied R & D in developing countries in terms of these parameters. Thirdly, it is an examination of actual emerging R & D patterns based on these strategies.

More specifically, in the study, an attempt will be made to examine the following questions:

-What are some of the relationships between science and technology and economic development as viewed by economists and others?

-What are the major constraints on the development of science and technology in emerging countries?

-What is the significance of international relations in science for the developing countries?

-What are the major problems and means of coping with them in regard to scientific manpower and scientific information?

-What are the most recurrent and/or important objectives for R & D in developing countries?

-What are some of the most frequently observed organization structures for conducting R & D in developing countries?

-Is it possible to classify the R & D patterns of emerging nations in a meaningful way?

I.3 The Definition of Some Terms Relating to the Study

In the course of working on other papers in the overall study, it was apparent that it was not possible to adhere to a simple set of unambiguous definitions. It is inevitable that the difficulties encountered in using a many-sided word like "research" in an international context will cause some confusion. However, some efforts to produce more precise terminology are being made, notably through the studies conducted at UNESCO and OCED. Some of these terms which are used throughout the thesis will be defined at this point and others with a more restricted usage will be defined as introduced.

Scientific Research can be meaningfully defined in several senses which are useful in the analysis of R & D in developing countries[1]:
1) principal kinds (basic, applied, development);
2) fields (various branches of physical, life and social science)
3) social functions (defense, medical, agricultural, industrial, etc.);
4) performance environments (industry, university, government, etc.);
5) administrative organizations (academic, councils, foundations);
6) performing units (project, division, laboratory, institute, etc.).

To define the principal kinds of research, a modification of the definitions used by the National Science Foundation have proved useful.[2]

Applied Research includes investigations directed to the discovery of new scientific knowledge that have specific commercial or social objectives with respect to products, processes, or service. This definition of applied research differs from the definition of basic research (below) chiefly in terms of the objectives of the reporting organizations.

Free Fundamental, Basic or Pure Research includes original investigations for the advancement of scientific knowledge that do not have specific commercial or social objectives.

Development includes technical activities of a non-routine nature concerned with translating research findings or other scientific knowledge into products or processes. Development does not include routine technical services to customers (clients) or other activities excluded from the definition of "research and development," below.

Research and Development (R & D) includes basic and applied research in the sciences and engineering, and the design and development of prototypes and processes. Excluded from this definition are routine product testing, market research, sales, promotion, sales service, research in the social sciences or psychology, or other nontechnical activities or technical services.

Oriented Fundamental Research is an additional category used by Pierre Auger that should be added to better define the general term "scientific research." This research, as free fundamental research, is centered on the fundamental sciences, "without entering the field of concrete utilitarian application . . . in doing this, he (the scientist) no longer has complete freedom in the choice of his objectives, for his activities are limited to a clearly defined sector of the sciences as a whole."[3]

This term is further subdivided by Auger into background research aimed at the collection of a wide range of data as on soils and the atmosphere, and field centered research which concentrates on a major natural phenomenon such as cosmic radiation. The notion of "fundamental oriented research" appears to be similar to the term basic development oriented research used by the International Development Center at Stanford Research Institute.[4] This is indicative of the search for new terminology to more precisely define research as it is used in the context of developing economies. Additional terms of this nature which are important are included below; they are not mutually exclusive or exhaustive categories.

Adaptive research is work done to adapt the existing production processes to the raw materials and resources of the country.

Prestige Research is done for the purpose of advancing national prestige regardless of its direct benefits to the economy and without regard to other national objectives.

Resources Research is done to advance the knowledge of the properties and amounts of resources in a region or country.

In regard to the fields of research, these will be discussed in more detail in the section entitled "Research Portfolio" but in general for the purposes of this study, unless otherwise specified, scientific research will be used to refer to fundamental and applied research and development in the following areas:[6]

-Fundamental Sciences (physical sciences, chemical sciences, biological sciences)

-Earth and Space Sciences (geology, geodesy, cartography, geophysics, seismology, climatology, hydrography, mineralogy, and oceanography)

-Public Health (eradication of disease, environmental sanitation)

-Fuel and Power Research (thermo-chemical energy, hydro-electric power, nuclear energy, solar energy, electrical power transmission)

-Industrial Research (metallurgical industries, chemical industry, textile industry, transport energy, telecommunication research, building and civil engineering)

Since many research related activities may be construed as research in the above definitions and classifications, the criterion to distinguish R & D from related activities "is the presence or absence of an element of novelty or innovation. Insofar as it departs from routine and breaks new ground, it qualifies as R & D."[7]

Economic Development includes both qualitative and quantitative changes, changes in the quality and quantity of resources and structural changes. It includes, for instance, changes in the prevailing technology, and changes in the habits of the people and of the social and economic institutions. This is in contrast with economic growth, a statistical term generally used to describe the changes in output, i.e., the gross national product of a country. Economic growth does not necessarily imply structural changes, and it is relatively easy to measure.[8]

> In the development of the more advanced countries, the political theorist of the nineteenth century has largely been displaced by the economist as the symbol of liberation of men's minds. In one sense the economist is now being hard pressed by the scientist as the key man in the realization of social progress - it is he who has, in large measure, the answers to the problems posed by the economist.
>
> --------G. B. Gresford, Organization and Planning of Scientific and Technological Policies[1]

II. Characteristics of R & D Patterns in Developing Countries

II.1 Flow Model of the R & D Process in Developing Countries

The essential relationships considered in this thesis are presented in Figure 1. It is recognized that this is an extreme simplification of a complex phenomena, but it is useful as a starting point to suggest the interrelationships of a number of major aspects of economic development and the patterns of research in such a situation. In general, itis similar to the models that have been used in other studies of various aspects of the research and development process in the Program of Research on the Management of R & D at Northwestern University. (This approach is fully developed in a recent article by A. H. Rubenstein in IEEE in Engineering Management.)[2]

The main factors involved are: the national goals of the country, the resources it has available and the constraints under which it operates, the economic development pattern, the objectives for applied research, the resources and constraints for appli d research, the applied research capability, the applied research portfolio, the results of applied research, and the "other factors" which influence the process.

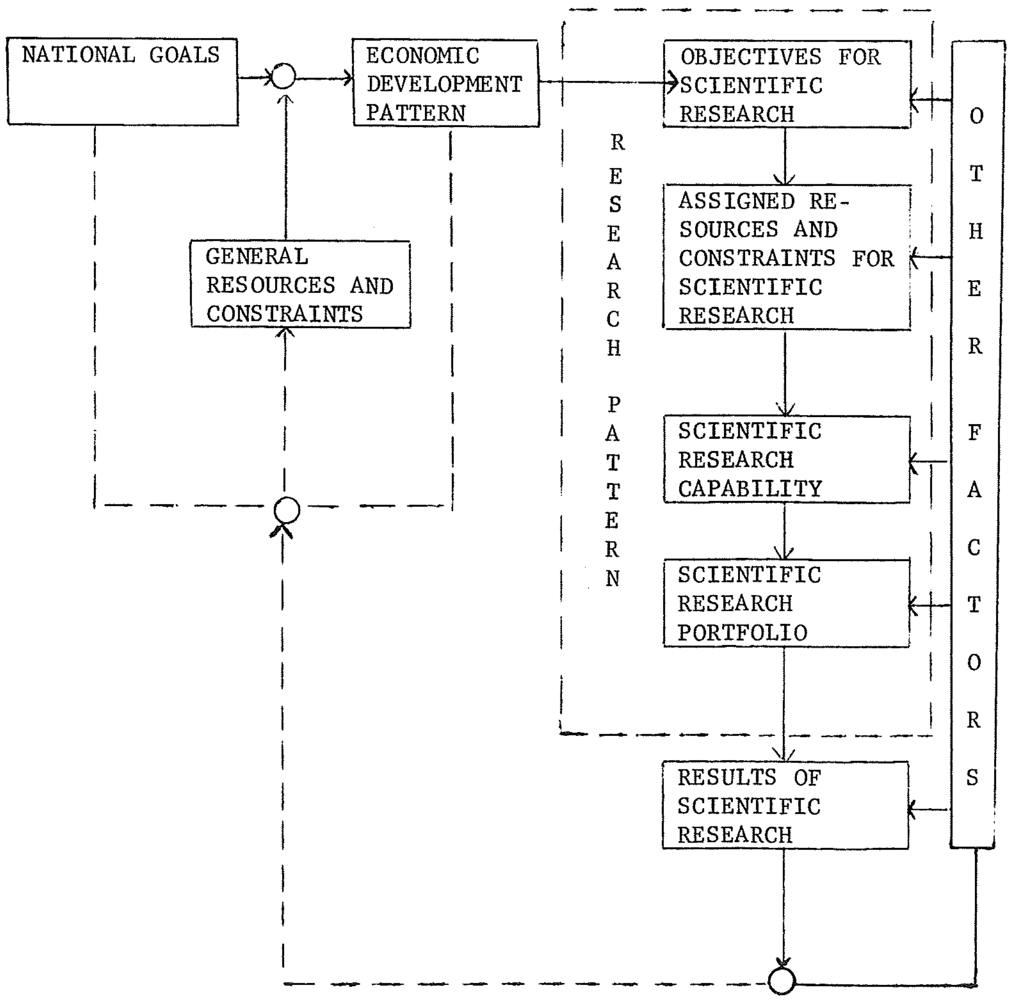
The main flow is indicated in the diagram shows, for instance, that objectives for R & D are shaped by the economic development pattern which in turn is based on national goals. It is important to note that the inverse holds true and that each factor experiences a feedback from subsequent factors.

The first set of factors, the National-Goals, include those goals that appear to be held by most of the developing countries, the general goals for such things as " a high standard living" or "education for all." However, many national goals vary significantly from country to country, i.e., some nations wish to maintain former colonial ties, others search for a new independent course, still others want to expand their area of influence and political control.

The second set of factors involves the General Resources & Constraints which influence the determination of national goals. Some examples that will influence the applied research pattern are: the educational base for the output of scientists and engineers;national values such as scientific tradition, religious belief, framework of law; international ties with advanced nations; the technical and economic base and endowment of natural resources; and finally the organizational base, in terms of social, economic, military, and political institutions which might encourage or constrain scientific research. At this point no attempt will be made to make an exhaustive and definitive statement of these parameters, since this is not a basis for developing a theory of economic development but a descriptive basis for studying the R & D process in

FIGURE 1

FLOW MODEL OF THE SCIENTIFIC RESEARCH PROCESS



Source: Albert H. Rubenstein and Earl Young. "An analysis of Alternative Strategies for Organizing the Applied Research Activities of Developing Countries." Department of Industrial Engineering, Northwestern University, 1963.

developing countries.

The third set of factors describe the Economic Development Pattern that occurs in a particular country, and results as a consequence of the first two factors, although not in a straightforward manner. The development pattern is reflected in all economic dimensions of a nation and is probably best described by economic indices on agriculture, industry, G.N.P. analysis, production, communication, education, health, military, and science and technology. These comparative indices provide a means to develop country profiles to use in comparing R & D patterns of development.

The remaining factors taken together represent the R & D pattern in developing countries, and form the basis for the analysis of the characteristics of the R & D process as outlined in Chapter II.

The scientific objectives for research of a nation cannot be completely and concisely stated by even the most highly developed scientific nation. The very nature of the scientific process and the interests of those who perform it make it difficult, if not impossible, to state explicit goals to cover all the scientific research activity in a given nation at a given time. Nevertheless, an attempt to understand this goal-forming activity and an examination of source material for a representative, if not exhaustive list of these goals, outline a major parameter within which R & D activity must take place. These goals also provide a primary measure of effectiveness of an R & D institute. Two features of this goal-forming activity, ie, the statement of scientific objectives at the national level, are considered due to the preponderant part they play in the R & D activity of developing countries. First, the role of the government which is becoming very inclusive covering the organization, financing, direction, and operation of R & D activity. There is significant variation in how governments participate in this process, but almost without exception the central government is a major factor in the R & D activity. Secondly, one of the overriding concerns of the developing nations appears to be the desire to catch up economically with advanced industrial nations. These desires when translated into an economic plan put into perspective, almost too painfully, the dependence on science and technology for their realizations. In the section on scientific objectives for research each of these factors is considered while a collection and classification of specific objectives is made in Chapter III. Regarding these specific scientific objectives it is essential to recognize that this examination is intended not only to find some of the many varied goals which are set but, more important, to find some of the major and common ends set for R & D in developing countries.

At the outset of this discussion it was pointed out that the national goals are modified by the resources and constraints of a nation. In like manner in the R & D pattern, the scientific objectives are modified and shaped by the assigned resources and constraints for scientific research as well as the constraints imposed by the environment ("other factors" in Figure 1). Of the many factors that might be considered as resources and constraints, four seem especially significant in understanding both the unique features of R & D activity in developing countries and important common problems. These four factors are international scientific relationships, manpower and training, the flow of scientific information, and the investment in R & D. Within the scope of this paper it is not feasible to treat each of these topics in detail and emphasis is placed on the first two topics.

Regardless of the final position a nation desires in regard to a scientific capability, it is inconceivable that a developing country with a rudimentary scientific base could achieve an R & D capability without heavy reliance on the world pool of scientific knowledge. International scientific relations have long been a characteristic of developed nations, but the extension of this activity to include newly developing nations is a recent phenomenon with the possible exception of some scattered colonial scientific activities. However, these efforts were not closely linked to economic development in the same manner that has been characteristic of activities since World War II.

Although not always explicitly stated, scientific objectives include, as a main target, the development of indigenous scientific talent whether for reasons of independence, defense or prestige. This resource, better than any other, mirrors a nation's attitudes of acceptance or rejection of science itself. It is one thing for a citizen to want a reactor for national prestige; it is quite another thing for the same individual to want to become a scientist when legal, governmental and military careers are the way to wealth and power. Also, to plan a realistic scientific manpower training program requires detailed consideration of the national scientific objectives, an analysis of current facilities and manpower available and a projection of future needs.

The flow of scientific information in developing countries takes on immediate significance when one considers the immense reservoir of scientific knowledge which is available and the many alternative ways of transferring this knowledge. Unfortunately, the problem is not simply one of transferring a body of knowledge intact. Who needs to know what information and where it can be obtained? Equally important, once R & D activity has produced scientific results, how can this information be disseminated and utilized? This information flow is vital to but, in a sense, parallel to the R & D activity itself. In the last decade, even in the most highly advanced countries, the "information explosion" has not been reduced to manageable proportions, and the problem is no less difficult in an emerging economy.

Investment in R & D while a major constraint, is the least directly connected in an operational sense with the R & D process itself. Yet, the funds limit the facilities available and the projects undertaken. They immediately impose the need for project selection criteria.

All these and many more resources and constraints in conjunction with national scientific goals shape the resultant <u>scientific capability</u>. This may be defined as the potential existing in a country for the performance of research work.[3] The scientific capability includes all those elements which Y. deHemptinne includes in a country's "operational network of research."[4] As he points out, this network can be analyzed from a number of viewpoints, i.e., the legal and administrative structures or the institutional aspect; the scientific resources of a country; and the financing of scientific activities. Emphasis in this paper is placed on the institutional aspect.

A key element of the R & D pattern is in the R & D portfolio or program. Here, also, it is impossible to discuss programs in general except in a limited way; for instance, the proportion of basic and applied research and fields of research which are of common interest to several nations. Of course, the cycle of R & D activity is not complete until <u>results of scientific research</u> are implemented and the net effect of this implementation, has, in turn, exerted its feedback effects on the nation and its development pattern. The problem of implementation is considered in the examination of the flow of scientific information. Finally, to temper this simplistic statement of the entire process as presented in this flow model, the ever present "other factors" are indicated as exerting influence at each step in the process. As stated, the balance of this chapter will be a more detailed analysis of the major elements in the R & D process in developing countries.

II.2 Objectives for Scientific Research

II.21 Science Policy

Today, it is virtually impossible to consider a nation's scientific objectives without also considering science policy, and by science policy we mean "the consciously developed coherent program for science and technology which are part and parcel of a government's thinking and planning for economic and social development" (Dr. Issac Arnon, Director, Agricultural Research Station, Israel).[1] "Nor is science policy an abstract concept. It names the complex of individual ideas, organizational biases, institutional attitudes, operational realities, temporary working arrangements, and necessary compromises out of which emerge national decision about where and how fast science will go, and about the national goals to which it should contribute"(OECD).[2] It is not the purpose of this paper to deal with science policy in a prescriptive or normative sense, nor to analyze science policy in depth from the point of view of either form or content. Instead, the purpose is to recognize that science policy in the sense defined above is increasingly the vehicle for collecting, assessing, promoting, and implementing a nation's scientific objectives. Secondly, in and of itself science policy as an organizational device must be considered if one is to completely understand the organization of science in any country.

This emergence of national science policies is essentially a post World War II development in highly developed scientific nations, i.e., "during the past twenty years it is mainly these countries which have made the almost simultaneous inventions of national research policy, as a new institutional mechanism for the development and use of science to achieve their national objective" (Dedijer).[3] Even among these nations there is a wide range in awareness of and refinement of science policy, but there seems to be great similarity in the systems evolving to handle science policy "irrespective of the structure of the State and the political system in power" (Y. deHemptinne).[4] This lies partly in the similar problem which these countries have had to face, i.e., "establishment of this mechanism and authority proceeded from explicit recognition that government policy instruments were required for the twin purpose of providing adequate support to scientific activity and harnessing its fruits to the economic and social objectives of the country" (OECD).[5] Also, in the opinion of G. B. Gresford of the Commonwealth Scientific and Industrial Research Organization of Australia, "the practice of scientific research at any level has now become so involved and so costly that provision for it can only be made on a satisfactory scale by governments. In developing countries this is an economic necessity."[6] Again, "problems stimulating development of national science policy in different countries are common. They result from decentralization of scientific effort and of governmental responsibility for it, which makes development of machinery to deal with overall national science policy extremely difficult" (OECD).[7] Finally, and most completely:

> "Since the strength, progress, and prestige of countries are today measured in part by their achievement in science and technology, science excellence is more and more becoming a national goal. National resources are therefore increasingly devoted to R & D. But resources however plentiful are always inadequate to all the demands placed upon them. Choices must be made among the multiplying and competing opportunities that modern science offers. They must moreover be made in the light

of overall national goals, since scientific and technical considerations increasingly underlie and affect major policy decisions relating to economic, and to national security and foreign affairs"(OECD).[8]

In fact, this recent awareness in the importance of science policy is resulting in the emergenc of a field of study in itself with serious interest at both the theoretical and practical level. Many country surveys of national science organizations and comparative analysis are underway such as those made in advanced nations through the OECD and in developing nations through the Research Organization Unit of the Department of Natural Science of UNESCO. Still, national science policy is a new process and "in a primitive state of development, even in countries with the most articulated mechanisms. Greater experience and theoretical understanding are necessary before a more systematic approach can replace the often ingenious but essentially imperical procedures and solutions that have been the rule to date" (OECD).[9]

As stated above, there are common elements of both structure and function which seem to be evolving in the many various national science policies which have been studied. The following descriptive model developed by the UNESCO Research Organization Unit of the Department of Natural Sciences[10] is useful as a starting point in examing the common organiztional elements of a states' science policy:

Function	Operating Mechanism
Planning science policy	National council for science policy
Deciding science policy	Ministerial committee for science policy
Implementing science policy	Institutions in national science network

Some strategies for organizing actual R & D operations and country R & D patterns will be examined in more detail in Chapter III, but the important common operational elements noted in this model of the infrastructure are:

(a) teaching andtraining scientific workers
(b) research operations
(c) financing and coordination of research
(d) auxilary research services
(e) scientific information services
(f) evaluation and registration of results
(g) use and application of the results of research

Coordinating and directing this structure is the national research council or equivalent body. Several options are available in the organization of this council and its authority such as the legal structure, organizational link with the government, financial authority, operational control, degree of centralization, spheres of activity, and selection criteria. For instance, N. P. Cognard[11] defines five stages of organization of national science policy based on increasing government involvement. Similarly, regardless of the organizational variety possible in the national science structure, certain attributes will increase its efficiency according to the UNESCO Research Organization Unit (see above model):

(a) "It should be self-regulating, i.e., with a permanent feedback from the institutions entrusted with implementation, to those in charge of elaborating national science policy.

(b) "It should keep in close contact for material information and guidance with government bodies planning economic and social development.

(c) "It should keep scientific workers fully and regularly informed of the national science policy, through factual or objective information supported wherever possible by numerical data."[12]

The experience of Israel which has a very advanced science network is also relevant in this regard. Dr. Issac Arnon indicates that a national science policy needs at least the following elements:[13]

(a) "A reliable form of central machinery, close to the heart of government, which can set the goals of policy and find ways and means of achieving them.

(b) "A major attempt to make optimum use of local and foreign expert manpower so that talent can make its full contribution.

(c) "Programs of education and training which make technology and experts indigenous, and not merely a foreign import and therefore superficial to the society.

(d) "A long-range organizational framework for research institutions which can encourage maximum effectiveness.

(e) "Ability to select from a host of directions and opportunities those most appropriate to the country."

Some of these points are of organization structure, some of organizational function, and some of program emphasis. Taken in an illustrative, rather than exhaustive sense, they point up these three areas which are necessary to consider in the development of an articulate science policy. In addition, the developing countries have some problems which are unique to their particular situation. First, they have only a fragmentary infrastructure and it is necessary to simultaneously develop a science policy which will "harmoniously integrate the various scientific institutions" (Y. de Hemptinne).[14] Offsetting this, however, as Dr. Issac Arnon points out, is the flexibility inherent in newer institutions and traditions.[15] One recurrent problem of organization is encountered in planning science policy in developing countries:

> In these countries "where the scientific resources are limited and the leaders of scientific schools not very numerous, some people are of the opinion that the whole network of scientific research should be grouped under the authority of a Ministry of Science, organically linked with the Ministry of Planning, and responsible for the framing and the implementation of a national science policy. Others think that each Ministry should retain the control or administration of research organizations connected with its 'raison de'etre', since scientific research undoubtedly stimulates the work of government administrations of the traditional type." (Y. deHemptinne)[16]

Of the many problems encountered in establishing and implementing science policy, two are especially significant in relating scientific objectives and the strategies for achieving them. One is the budgetary problem; the other the problem of determining priorities. In the new field of research-on-research which deals with such topics in the management of research in industrial corporations and other institutions, theories, and pragmatic approaches are being developed and tested. This is not the case at the national level. Conflicting goals in diverse parts of the economy or within the government make it virtually impossible to assess projects along a single parameter and no adequate theory yet handles the problem in terms of multiple parameters. In terms of the budget, the problem becomes one of developing a system that will:

(a) "serve to reflect national priorities among alternative possible scientific programs,

(b) "serve as an instrument for planning the allocation of national scientific resources, and

(c) "assist those responsible for the nurture of science to secure the resources that they feel necessary to their task: (OECD).[17]

In terms of the determining priorities in both fundamental and applied research, the problem has its source:

(a) "partly in the uncertainties and unpredictability inherent in all scientific endeavor,

(b) "partly in the difficulty of comparing dissimilar activities and their potential contributions to different national objectives, and

(c) "partly in the fact that the very concept of establishing priorities --and the concept of planning that is allied to it--is still believed by many to be inconsistent with the freedom of inquiry that has been the traditional lifeblood of fundamental science (OECD).[18]

In countries with a scientific tradition, and this includes a few of the developing countries although in a limited sense, this last point of seeming inconsistency of a system of priorities and the freedom of inquiry of the individual scientist is fundamental to the proper functioning of a national science policy. It is easy in a highly scientific nation which has evolved a system based on a long standing scientific tradition to minimize the problem i.e., "the existence of a national science policy implies no abridgement of the scientists' autonomy in the conduct of research" (OECD).[19] True as this may be in a developed economy where there is an articulate scientific community, the situation in a developing country is entirely different. Overzealous attempts to organize science can result in unnecessary restrictions on the scientist's activity.

Turning to the content of science policy three general observations are important at this point; specific science policies stated as scientific objectives are analyzed in Chapter III. First, science policy is interrelated to all other aspects of a national policy, i.e., economic, social, military, foreign, aid and education. "Maximum exploration of scientific opportunities requires programs that combine concern for the growth of science itself and provision for the rapid deliberate application of its fruits to human welfare. That is the substance of science policy in the full sense as denoting consideration of the interaction of science and policy in all fields" (OECD)[20]. Secondly, each national science policy is unique, answering the specific needs of a particular nation at a given stage of development. "Depending on circumstances, philosophical and moral traditions, the level of economic development, and the existing social system, the synthesis of knowledge and action which a government must achieve in framing its science policy will develop its proper character" (OECD).[21] Thirdly, in terms of government action, science policy has two fundamental aspects (Y. deHemptinne),[22] vis.,

-measures taken to provide the resources needed to develop scientific research and for increasing its productivity.

-measures designed to harness scientific activity not merely to the advancement of human knowledge in general but also to the economic and social welfare of the population.

The first of these categories includes measures taken to build a scientific apparatus and is discussed throughout the balance of this chapter under Assigned Resources and Constraints for Scientific Research. The second is considered immediately in the next section, Science and Economic Growth.

> There should be no mistaken notion that basic scientific research will optimally promote economic growth in less developed nations.
> -----Paul W. McGann, Science as a Factor in Economic Growth[1]

> There is reason to believe that, in a market economy, resources allocated to the advancement and spread of knowledge tend to be less than optimally required for efficient long-term growth of the economic system as a whole.
> --------Ministers Talk about Science[2]

II.22 Science and Economic Growth

II.221 Science in Relation to Economic Theory

Science and technology are regarded by many as the cornucopia of modern life and this is well recognized at the policy level in developing countries. Nowhere are the hopes higher for economic growth through science and technology than in these lands, and the reasons for such attitudes are clear. Several studies have been made using quantitative analysis which show that "the higher is the economic development of a country, the greater is the percentage of its Gross National Product invested in research" (Makagiansar).[3] None of such studies can validly demonstrate that growth in GNP is caused by investment in research but the general faith that this is the case is widespread. Also, comparing advanced economies at different stages of development indicated that the research ratio tends to be higher in countries with higher per capita G.N.P., and, in general, countries with a higher per capita G.N.P. have a substantially higher research ratio than countries with a low per capita G.N.P. (Makagiansar).[4] The advanced countries typically spend more than one per cent of G.N.P. on R & D, while developing countries spend less than 0.25 per cent. This general relationship is modified by the structure of a nation's industry, since some industries such as aircraft and electronics have a high relative expenditure on R & D whereas industries such as furniture and textiles tend to have much lower relative expenditures. Countries such as Australia, Finland, Canada, Iceland, and Norway in which G.N.P. depends importantly on agriculture, forestry, mining, and fisheries, (i.e. on industries with a relatively low research input), show a relatively low research ratio in relation to per capita G.N.P.;" yet the gross national products per capita in some of these countries are among the highest in the world.[5] Perhaps one of the most relevant observation for the future of the less developed countries is the opinion that "it appears that the amount of scientific effort required to bring forth a one percent increase in productivity per man-hour in developed nations is becoming greater" (Paul W. McGann).[6] This, if true, means that an increasing share of the G.N.P. of these nations must be devoted to R & D to maintain their growth ratio. To Dr. Bohuslav Starnovsky, Director, Institute for Planning Scientific Research, Czechoslovak Academy of Sciences, this means, "it is necessary to plan the appropriation of funds for science so that it is able to develop at a faster rate than technique, the rate of development of which must, in turn, keep ahead of that of the growth of industrial production."[7] To an extent this may be offset for the developing countries by the possibilities of adaptive R & D and the increasing world body of scientific knoweldge available for their use.

However, speculation about a general relationship is far from a clear understanding of the complex and many faceted interconnections in this relationship. In fact, traditional economic theory for a long time ignored the technological framework of change. Standard textbooks on economic theory must have not until recently considered education and scientific research as critical factors in explaining economic growth. These factors of change were considered as exogenous or "residual factors whose influence has been eliminated from the theoretical models by the traditional assumption of ceteris paribus--other things being equal" (Makaginsar).[8] Postwar experience has changed the emphasis to economic development and economists such as Freeman, Poignant and Svennilson "have increasingly felt the need to penetrate the facade of ceteris paribus and to investigate the mechanisms of technological and social processes in order to arrive at a more complete explanation of economic growth" (Makaginsar).[9]

New economic theories have been developed which treat investment in scientific research as types of investment having different degrees of direct influence on the economy. As a result, they are now regularly treated as one of the principal factors of production in the economic process. Still, knowledge of the relationships between science and economics is embryonic and a full solution with quantifiable variables may never be reached. However, economic theorists have progressed in devising refined analytic models ranging from simple statements of inputs and outputs to complex constructs of mathematical equations. In the decade after World War II, economics generally believed that capital formation as opposed to investment in human resources was the answer to rebuilding national economies, and perhaps was for developed nations. The argument was also applied to newly independent states due to their lack of basic industries and adequate economic infracture for self-generating economic growth. The argument according to Makaginsar ran as follows:

> "by not consuming all that can be produced a portion of total production can be used for buildings, roads, bridges, harbors, machinery, etc. It is then argued that the deliberate restraint of consumption and the consequent accumulation of capital stock, combined with certain social and cultural developments will produce the characteristics required for the economy to 'take off.'"[10]

Economists did not omit other determinants of economic growth such as education, manpower training, health, social conditions and political stability, but generally the most important factor during this period was capital formation. Moreover, "experience has shown that development programs established in the 1950's often concentrated too heavily on real capital accumulation to the neglect of education and research" (OECD).[11] One should not think of these 'residuals' as necessary, but secondary, to capital in their contribution. There is evidence to the contrary and most attempts to assess the influence of changes in the principal factors of production in mature economies "show that the rise in capital/labor ratio accounts for only a small part of the long-term increase in productivity while the traditionally exogenous variables, usually grouped together under the heading of "technical progress," account for up to 90 percent of increases in real product per person employed" (OECD);[12] M. Patin explored "residuals" to some extent in his thesis;[13] and M. Makagiansar cites several studies bearing this out:

> "In a study which covered the period 1899 to 1957 Kendrick concluded that in the United States the combined inputs of the traditional factors of production accounts for only one half of the rate of the growth of national product and less for the latter part of the period. Professor Solow, Massel, and Aukrust, although studying different economically advanced countries came to similar conclusions that up to 90% of the growth in production was due to residual factors. In the United Kingdom, Professors Roddaway and Smith found that 75% of the increase output per head in manufacturing industries for the period 1948-1954 was due to "residual" factors. In respect to agricultural production Professor Schultz found that for the United States between 1910-1914 and 1945-1949, for Argentina between 1912-1914 and 1945-1949, for Brazil between 1925-1929 and 1945-1949 and for Mexico between 1925-1929 and 1945-1949, the percentages of additional output attributable to 'residual' factors were respectively, 83, 62, 45, and 50."[14]

Much has to be done so these 'residuals' can be quantified and used in the economic growth models. In addition Makagiansar cites the following additional problems (a) "How are science and technology to be defined for purposes of economic analysis, (b) How are the elements which make up science and technology related to corresponding elements in other residual factors, (c) What proportion constitutes science and technology within the aggregate of 'residual factors,' and perhaps the most difficult one, (d) what variations in investments in science and technology occur at different stages of economic development."[15] While ideally, the return on investment in science should be ascertainable and evaluated in terms of other attractive investment opportunities, investment in science can, in addition, be evaluated in terms of its contribution to the scientific network as well as the production of specific results. This is of paramount importance to those nations desirous of creating their own scientific capability; they need a capacity to create scientifically on a sustained basis.

Regardless of the above theoretical problem, policy makers and administrators are faced with the pragmatic problem of relating science and technology to economic development in their particular countries. Even though this is a recent problem, considerable experience is developing and in turn becoming the basis for further knowledge of the relationships between science and economic growth. The focal point of this relationship is increasingly being expressed in a detailed science plan. Here more than at any point in a nation's administrative process, we can find in some detail the explicit and implicit relationships in the matrix of scientific activity.

> To avoid the risk of serious stresses, development must follow a pre-established plan, covering the economic, financial, scientific, technical, social and political aspects of local problems.
>
> -------P. Piganiol, <u>Selection Criteria for Techniques to be Introduced in Developing Countries</u>.[1]

> Science has typical features of its own differing from those of industry. Its planning is subject to specific laws which has not hitherto been sufficiently studied.
>
> ---------Dr. Bohnslav Starnovsky, An Outline of Scientific and Technical Policy

II.222 The Relationship between Research Planning and Economic Development Planning

In this analysis, a few definitions are included at the outset which are currently being used by the OECD[3] in their studies on the organization of R & D in member nations. Planning research means to forecast the needs of manpower, finances, equipment and all other production requirements of the industry of discoveries and invention, and the significant directions of the growth of science and to allocate the resources to each one of these elements of research work according to priorities consistent with the principal national objectives. To plan research means to plan the research potential, the research effort and the research programs for each research production unit, for each kind, field, social function, production environment and administrative organization, and finally for a whole country.

The research potential (capability) is the potential existing in a country for the production of research work, for the production of inventions and discoveries.

The research effort is the effort made to increase annually the national research potential.

The research program is the distribution of the research potential along the various branches of research existing now in the world and in relation to the national plans and objectives. Research program can be defined on the level of a project, a laboratory and institute, or on the level of any of the categories, types, kinds of institutions performing research work using the definitions of research mentioned at the outset. (In our program of research on the management of research and development at Northwestern University, we use the term "project portfolio" to describe the specific allocation of resources to projects or programs within an R & D organization.)

"Research planning" in a developing country needs some qualification. Just as there are many stages of economic development, research planning in developing countries varies from the rudimentary to the level of sophistication we find in India. Secondly, plans can become another way of stating dreams and aspirations. Already these countries have such high expectations from science and technology that there is a danger that disappointment will follow unrealistic demands which may be placed on the planners. Thirdly, there is so much continual day-to-day pressure--political, economic, etc.--that constant compromise frequently emasculates long-run planning. Finally, there is a tendency to think that research planning can be done easily by an existing government agency, often resulting in hasty and ill-conceived plans. D. G. Kingavill[4], of the South African C.S.I.R., which is under a Ministry of Science reporting directly to the Prime Minister, urges against this. "A planning organization is required for the setting of intermediate and long-term goals, and for systematizing the effort for achieveing them. Such an effort can only be planned, executed and co-ordinated with other efforts through an interlocking set of institutions, each of which take on its own task or purpose, sets its own intermediate and long-term objective, and organizes its own effort to achieve this."

Outside of observations such as those above, it is difficult to generalize about research planning in developing countries. In fact, it is difficult to generalize much about research planning in the developed countries such as we are able to do in economic development. A beginning in this direction has been made by Stevan Dedijer in his examination of research planning in India[5] in which he develops a general framework of analysis. A brief review of this analysis is included because it summarizes rather thoroughly the 'state of the arts' in research planning today. Its primary assumptions are based on Dr. Dedijer's studies of science in developing countries, and these assumptions themselves would form the basis for further investigation.

To begin, he notes the following assumption underlying the Indian Research Plan:

> 1) "research policy, that is the promotion, co-ordination and planning of research work, is just as important for the achievement of national goals and must have as high a priority as foreign, defense, economic educational and other policies;
>
> 2) "the effective planning of industry, of agriculture, of education, of any other sector of national life is impossible without planning, at the same time, the development and utilization of research;
>
> 3) "the planning of growth of any sector of society requires a simultaneous planning of a certain research potential and a research program connected with the growth of the given sector. The priorities in planning of various sectors must include the corresponding priorities in planning for that sector;
>
> 4) "one major task of national planning should include the development of research potential at a rate and in the direction most needed by the national development plan.
>
> 5) "the national plan should include as one of its major tasks the fostering and creation of demand for research by industry, agriculture, transport, and all the sectors of the economy, by the universities and the scientific community."[6]

He continues his analysis by noting that research planning on a national scale includes the following activities (some of these activities go beyond those usually associated with planning as a staff activity and include elements of implementation):

> 1) "to predict the principal trends and directions of growth of research (basic and applied) in physical, life and social science by studying its development aborad and within the country;
>
> 2) "to forecast and formulate the targets of needs of manpower, finances, equipment and institutions necessary for the country on the basis of the results from (1);
>
> 3)"to allocate the existing national research resources to appropriate social sectors according to priorities consistent with the principal national objectives;
>
> 4) "to stimulate the demand for research of the most modern kind by industry, agriculture, the scientific community and all the other social sectors;

5) "to forecast the need of organizations for communications both within them and among them necessary for the optional production and optimal utilization of research results;

6) "to co-ordinate the demand for research resources with the industrial, agricultural, educational and all the other plans and policies;

7) "to evaluate how and with what effect the above process is carried out in time."[7]

Finally, Dedijer notes that research planning can be carried on in three degrees of approximation. The first he calls global planning of research potential. This assumes that the basic social objective is to increase the Gross National Product and increasing the research potential will eventually contribute to the growth of the G.N.P.

In the second approximation, the growth of the research potential and of the research effort is correlated to the specific targets of economic and social development. This type of planning is also advocated by the OECD in their recent attempts to assist "developing" countries in their organization, i.e., Turkey, Greece, Italy, Spain, and Ireland, although by many standards some of these economies are relatively developed. This second approximation can be done through (1) an analysis of the current state and the expected growth of the production processes in all sectors of industry; (2) and analysis of the processes of research necessary to promote growth of those factors in (1) above; (3) ranking and selecting the most important projects in (1) and (2) above according to economic, technical, socio-political criteria and time feasibility; (4) guiding the development of the research potential on the basis of studies made under (1) and (2) above. This approximation should also be based on major social and economic objectives and the sum of the growth rates of the separate components should not exceed approximation one.

The third approximation calls for determining major research trends and planning research in accordance with these trends. This is favored in developed countries, but it is in a low state of rationalization. Underdeveloped countries would find it difficult to orient a major share of their effort to this "band wagon" approach, but they might keep abreast of trends and, in turn, pursue some on a selective basis.

One of the major observations one could make about Dr. Dedijer's analysis is the recurrent theme of research based on economic and social objectives. It determines the area of research, amount of expenditures and the basis for selection criteria among alternative proposals. Similar approaches are found throughout the literature and provides the basic assumption for linking research planning to the economy. It is deceptively simple and yet it seems to be gaining acceptance in many areas, but notably the OECD and UNESCO: that is, to derive the science plan from the national plan for economic development. One obvious reason for this is the wide spread existence of and use of National Plans for Economic Development which normally start out stating national objectives and policies.

One variation on this major theme has been developed by M. Makagiansar;[8] in Dedijer's scheme it would be a second approximation since it derives research targets by a sectoral analysis of the economy. Makagiansar makes a useful distinction in types of research. Instead of using the notions of fundamental, oriented fundamental, applied, and developmental he seeks to define "problem--entities in a "development" sense. This method is functional and derived from an approach that begins from a policy-making point of view. This approach implies that the better the development plan, the clearer the targets and "development problem-entities." Further, research planning proceeds simultaneously at two levels: (1) the scientific target level and (2) the scientific operational problem level. At the scientific target level planning is oriented to determining the above mentioned "problem-entities," while at the scientific operational problem level efforts are directed toward integrating the research into creating and cultivating conditions -- economic, social and cultural -- conducive to the development of the economy."[9] In a sense, it is the feedback not only of the research results themselves, but the incorporation of the research process in the development of the economy.

In more detail at the scientific target level, examination of the National Development Plan will reveal a number of subjects which require scientific and technological research. This list will probably be extensive and need to be trimmed down. For Makagiansar this means grouping the subjects into " a number of substantial and, if necessary, interdisciplinary research projects." Once these have been developed, these projects can be related to sectoral targets in the economic development plan in terms of their time feasibility. "Here again, in view of the objectives and the policies of the Plan, it is possible to classify the comprehensive research programs in the order of priorities."[10] We are still left with the problem of making a selection among alternatives, but for Makagiansar much of this difficulty is circumvented by using "the implicit and explicit demands of a hierarchy of imperative" in the economy. It would seem this approach would be best suited to those situations where choices were sufficiently limited and the imperatives of the economy sufficiently clear in terms of time preference to practically dictate the selection of projects. Otherwise, we are again faced with the need to fall back on the judgment and expertise of planners and administrators. This problem of project selection is one of the areas of concentration in the program of research on research management at Northwestern University; the current state of the arts in this area has been examined and a bibliography on the subject prepared by N. R. Baker and W. H. Pound.[11]

Two observations indicate the inherent limitations in this method. First, development plans in relation to the time horizons of basic science are short, i.e., three to five year plans might be adequate to set up and accomplish results in a program of applied R & D, but programs in basic science are usually much longer. Secondly, regardless of the type of science discussed, the planning of research on this basis is too heavily dependent on the plan, i.e., there is no allowance for serendipity and the freedom of the scientist is constrained. In regard to the first of these observations one should note that problem-entities includes research at all levels, although one can immediately counter with the observation that this is still a narrow constraint and many basic research problems may not receive necessary attention. Perhaps some of the difficulty is resolved by noting Dedijer's distinction between planning science and planning research; he maintains we cannot plan science, only research. This leads us to an interesting and not exactly trivial point: while planning research might minimize the chance of working on certain important basic problems, not planning does not assure us that these problems will be tackled either. Secondly in developing countries, there is an emphasis on initiating as well as expanding activities and so long as the need for a fundamental research capability as a pre-condition for both doing original basic work and assimilating fundamental work from abroad has been recognized and some provision made for building this capability, the extent of and direction of this capability becomes a less immediate problem.

In regard to the second point--the loss of freedom by the scientist due to research planning based on economic development--the main defense marshalled is limited resources. This is fundamental and cannot be circumvented, there simply are no funds in most cases to allow complete freedom to the individual scientist or technologist. To leave it at this begs the question. Obviously the scientist or technologist can leave the country, or continue working under what he considers less than optimal conditions. The problem is more one of resolving the difficulty within the constraints of achieving national economic objectives. Some aspects of this problem are considered in section II.32, Manpower and Training. Secondly, while the economic plan may determine the research plans in the short run, say five years or less, the research plan, working at the operational problem levels will generally exert a feedback on the economy. It is problematic to what extent a given country will be influenced by this flow of information and will incorporate it in developing the national plan; nevertheless the option remains. Further reference to the scientific operational level will be made in section II.33, The Flow of Scientific Information, where other problems of this nature are considered.

The OECD is using a similar line of reasoning in their assistance to less developed member nations. This assistance is rendered in what are called Pilot Team Projects and made up of scientists and economists of the participating country. The purpose of these projects is to examine the specific ways scientific and technological research can best be related to problems of industrial and agricultural production and social welfare within the National Development Plan. Primary elements of the work to be done include (1) making a survey of the R & D potential and (2) making an analysis of the requirements for R & D in relation to economic growth. The underlying assumptions of these Pilot Team Projects are of interest, as they help to etch in an area of consensus on the important relationships between science and economists.

First, in contrast with Makagiansar who identified 'development problem-entities,' the OECD Team Projects employ a classification of scientific research which can be related to the social objectives of a given country. In developing countries it is assumed that economic objectives are of primary importance. By examining the economy, areas where technological change can be introduced can be found by means of the technological surveys to augment this economic growth. These surveys, in turn, are a basis for determining where scientific and technological research can be used to effect these changes. The technological survey must be considered in terms of the constraints revealed by a survey of the scientific potential which enumerates the major constraints on what it is possible to achieve. General priorities are determined by the classification of research and by priorities in the national development plan. This, in general, is the approach used and follows the main outline of the Makagiansar approach. The main difference is in the classification of research for planning purposes employed by the OECD.[12] These categories, by social effect include:

1) <u>Research with extra economic objectives</u>. This includes, besides fundamental scientific research, research with political objectives, i.e., prestige or defense.

2) <u>Research with economic objectives which cannot be accurately defined</u>. This includes research such as studies of the properties of natural resources and topics which appear to have economic importance, but no clear-cut economic objective can be pre-assigned.

3) Research with defined economic objectives. This category includes research designed to solve problems of economic importance. In developing countries this includes "adaptive" research--that is research which utilizes results obtained in developed countries with minimal modifications to suit local conditions.

4) Research with general welfare objectives such as medical research.

Two constraints place emphasis on category three and provide a rationale for ranking these categories, thus furnishing us with a selection criterion for choosing R & D projects. The reason the OECD relies on this determination of relative emphasis by type of research is the current lack of information on how to determine the economic returns to scientific activities.

> "The general social objectives of the country give a first quantitative guide to where the emphasis should be in scientific plans. In the case of developing countries with which we are specially concerned, the social objective of the greatest importance should be (and usually is) the economic one: to maximize the rate of growth of income per head, (capita), within a certain time horizon."[13]

Therefore, using this line of reasoning, it follows that where income is near subsistence levels, a first criterion is to do scientific research in a manner that will maximize the contribution to increasing the rate of growth of income per capita. This places emphasis on category two and three. Secondly, the subsistence level of living minimizes the opportunity for sacrificing current income for long-term gains. Another criterion is provided by this time constraint. The nearer the income is to subsistence levels the greater the emphasis should be on relatively quick yields. This results in a priority on category three research. The other categories, especially category one, receive relatively less emphasis.

> "The main argument here is not so much the risk involved (though there is a risk) in the research investment as the fact that it usually takes a long time for such research activities to yield results which will have a significant and desirable economic impact" (OECD).[14]

The specification of these categories are part of an extensive framework of analysis used by the Pilot Teams and are probably necessary for a systematic approach to field work. However, a system of classification is not necessarily a statement of an inherent relationship, and we once again fall back on the priorities of the national development plan as the basic criteria for determining the science plan. The system of classifying research does provide a means of making refinements within a category and as such can be used in more complex economies. In fact, the OECD framework is perhaps best suited to countries which have an economy fairly well advanced, perhaps to the "take off stage" using Rostow's terminology.

This matter of distinguishing stages of economic development and the appropriate techniques of organizing and directing scientific activities at each significant stage, has not received adequate attention. Paul W. McGann of the U. S. Department of Commerce makes a distinction along these lines and refers to less developed and middle income countries. The latter are characterized by a much wider spectrum of choice inselecting among alternative investments for economic growth or for other purposes, "possibly a spectrum even wider than available to the more advanced countries."[15] Like the lesser developed countries, they may solve a great many of their problems by adaptive research, using techniques with some modification from the developed countries. At the same time they develop problems, like advanced countries which require basic research and the discovery of new techniques. In making decisions, the middle-range countries tend to be like the advanced countries in two respects, McGann points out. First, crucial problems tend not to be self-evident as is most often the case in less developed countries, and they require more data for their identification. Secondly, since the problems are unique they require indigenous experts either to adopt known techniques or develop new ones. This dichotomy bears examination but it points the way to an analogous development in research to the stages of economic growth popularized by W. Rostow.[16]

These stages of development constrain the types of technological change that can be introduced at a given time in a given country. Many interesting programs can be devised in this manner and some of these are considered in Chapter III. However, before considering these programs, it is necessary to turn to an examination of scientific resources and constraints and to the institution-building problems which are encountered in initiating and developing a research potential. Up to this point we have examined, in a descriptive and non-critical way, the 'state of the arts' in science policy and science in relation to economic growth in order to clarify the goal-forming process of determining scientific objectives at the national level. It is not the purpose of this thesis to investigate the complex relationships between research and development and economic growth.

II.3 Assigned Resources and Constraints for Scientific Research

II.31 International Relations in Science

> "While nations turn this way and that endeavoring to find common ground between positions which because of ideological differences are difficult to reconcile, science appears as one of the rare common languages which are not only a means of communication but also an instrument for the understanding and rapprochment of culture."
>
> ________ Min. Villecourt and Dumesnil
> "Science as an Instrument of Diplomacy"

II.311 The International Nature of Science

While international relations in science on the present scale and with its closely associated economic and political considerations is of recent origin, science has always been international. The need of the scientist to communicate with others who have similar interests cannot be limited by national boundaries if science is to progress. This may be the most direct and enduring bond in establishing international scientific relations, but, in addition, certain forces are operative which are increasing the number, scope, and scale of these relations.

First, there is an increased interest in the synoptic sciences; i.e., meterology, geophysics, oceanography, the geography of diseases, etc., which requires observations in many parts of the world. Secondly, many scientific ventures are expensive and few nations can afford to undertaken them independently. The best example of this is probably space research; another is high energy physics. Thirdly, so much is being discovered by all nations that each one can learn from the others. Fourthly, an increasing number of common world wide problems such as over-population require a scientific approach. Finally, many technological problems which can be approached nationally are more economically done internationally, i.e., transportation and communication systems and power grids used at peak periods in different nations. In addition, international cooperation in reinforced by commonly accepted benefits. Important among these is the contribution made to broader economic and military objectives and the enhancement of national prestige resulting from such cooperation. A myopic perspective might ignore the possibility that this could be a transitional phase in the evolution of science, but current trends certainly indicate an increase in this interdependence.

This cooperation can assume many forms including training and visits abroad; contacts through professional associations; special projects of collaboration, support through international organizations; bilateral and multilateral agreements; multinational corporations; and agreements with foundations and universities. A more systematic examination will be made of these various forms of cooperation in Chapter III. At this point our attention is directed at the international scientific network in which they are but different elements. This can probably best be done by looking broadly at international scientific cooperation in the last hundred years or so, the period in which cooperation became institutionalized in its present and varied forms. Much of the following brief review of this period is from a report prepared for an OECD meeting of ministers of science.[1]

II.312 The growth of International Scientific Organizations

Among the first of these organizations were the international scientific congresses, beginning with the International Congress of Economists in 1847 and followed rapidly by many others including the International Agricultural Congress in 1849; the International Health Congress in 1851; and the International Congress of Meterological Observations at Sea. As scientific discoveries were made at an accelerating rate, coordination among specialists was hampered. In fact, the congresses soon established permanent bureaus to keep the membership informed and prepare periodic meetings. This was the origin of the first permanent international scientific organizations with administrative machinery. Two of the oldest are the Universal Society of Opthalmology, 1861, and the International Association of Geodesy, 1864. All institutions of this type were initiated by scientific circles and had the limited objectives of cooperative study and joint resolution of scientific problems. One of the best examples of this type of organization is the International Bureau of Weights and Measures, but it differed from all others in that it required building a laboratory for joint research. By 1914 there were 53 of these international organizations including both governmental and non-governmental organizations for pure and applied science not including the social, medical, and agricultural sciences.

The proliferation of these international organizations made it seem essential to have, in turn, a means of coordinating their activities; there were often several organizations covering one scientific discipline that made rapid intercommunications necessary. The first of these, the International Association of Academies was formed in 1900. It failed due to the preponderant influence of German-speaking academies and was followed by the International Research Council in 1919. The evolving increased activity of international organizations can be traced in the objectives of the Council, i.e.,

> "to coordinate international activities in the various scientific disciplines and their applications, to foster new international associations or unions, to guide scientific activity in fields where no international organization existed, and to approach the governments of Member countries with a view to promoting the study of matters relevant to their interests."[1]

Apparently this organization failed due to the exclusion of Germanic academies; in 1931 the International Council of Scientific Unions was formed, functioning to date as a federative body.

Prior to World War II, there were only two international research stations founded with the objective of providing research facilities for scientists who wished to carry out their own research projects, i.e., the Naples Zoological Station established in 1870 and the Jungfraujoch Scientific Station established in 1930 in Switzerland.

From 1919 to 1939, 39 more scientific organizations were established partly as a result of realizing the benefits of close cooperation made apparent during the war. However, the activities of these organizations with few exceptions (see above), still had as their principal function:

> "the promotion of personal contacts and exchanges of information and the dissemination of information on findings and methods of research undertaken in their various Member countires, rather than co-ordination of this research or its implementation by joint programs or in common establishments."[2]

However, an important change was apparent in the condition under which these organizations functioned after 1919, although it was not a significant factor at the outset. Namely, the organizations ceased to be purely scientific in their objectives and direction as they had essentially been prior to 1914. During that pre-war period, the narrow scientific activities of the organization raised no significant political problems since they did not affect issues of major concern to governments. Then too, costs were low. The organizations were run by and for scientists. After World War I, an attempt was made by the League of Nations to coordinate all international activities in every sphere. According to Article 24 of the Treaty:

> "All international bureaus formerly set up by the collective treaties will, subject to the assent of the Parties, be placed under the authority of the League."

From this point on international scientific relations had to be considered from this dual point of view, i.e., the scientific and the political. Through the years the ambiguity caused by this duality has increased and may account for some of the difficulties that characterize international scientific cooperation today (see section II.313, Characteristics of the Current Organizational phase). World War II accelerated these trends by providing additional examples of how much could be accomplished through international scientific cooperation, the most outstanding example of this being in the field of nuclear research. Additional impetus was also given by the need to repair damaged economies, especially in Eurpoe. Finally, the war demonstrated to everyone the fundamental role of science in building and defending societies, further reinforcing the links between science and political aims.

> "At once benefiting from the achievements of science and technology and called upon to bear an ever-increasing share of their costs, governments saw in scientific cooperation a means of achieving some of their national and international objectives more quickly or more effectively. Theretofore a means of action, interchange, and communication largely reserved to the scientific community, international cooperation in science also became an instrument of political, economic, and social and military action."[3]

As a consequence, the growth of international scientific organizations accelerated; between 1945 and 1955, 58 new organizations were formed and by 1963 there were over 250 intergovernmental and nongovernmental organizations engaged in scientific activities.[4] A great deal of the activities of these organizations remains at the level of providing a means of maintaining communications links between scientists; however, closer cooperation at the level of joint operations is becoming more common. The International Council of Scientific Union has received $175,000 annually since 1947 to work in a liaison capacity and in organizing large-scale international projects such as the Geophysical Year or the International Years of the Quiet Sun.

The intergovernmental organizations have a variety of forms with some specializing in a particular field with their own facilities such as CERN and EURATON in nuclear research and others doing no research directly but sponsoring it in specialized fields such as the World Meterological Organization (WMO) and the World Health Organization (WHO). Other more general organizations include scientific objectives as only a portion of their basic objective, ie, UNESCO and OECD. In all there are some sixty of these organizations concerned in some way with science; the number reduces to thirty if we consider only those which promote, coordinate, or engaged in research activities. The greatest number of these organizations is found in Europe and it is here that they are most active in research. Some of these international organizations are truly international, encompassing all nations or at least operating on a world wide basis, such as United Nations agencies and the International Bureau of Weights and Measures, while others are regional in scope such as the Organization of American States. Finally, one recent development provides another dimension for considering these organizations, i.e., more highly specialized organizations have developed directly or within the more general organizations. These organizations are linked by common economics and political objectives, the most notable example is the United Nations with UNESCO, WMO, and FAO. Other examples are the regional organizations in Europe such as the European Nuclear Energy Agency (ENEA) and the European Launcher Development Organization (ELDO).

II. 313 Characteristics of the Current Organizational Phase

Prior to 1945, little or no distinction had been made in the various levels of economic and scientific development of the nations participating in these international organizations. So long as scientific objectives were predominant, and the participation on an individual basis, exactly what nations and how great their representation was of secondary importance. With the emergence of an array of new nations there were changes in organization emphasis. For convenience it is possible to consider the nations of the world as falling into three categories: the "scientifically developed" including Western European nations, U.S.A., Japan and the U.S.S.R.; the "developing" countries including India, Brazil, and Argentina; and the "less developed" countries most generally located in the tropical regions with little or no institutional structure to encourage scientific activity. As a consequence, the United Nations and its specialized agencies concentrated with increasing emphasis on the less developed areas. In doing so, these agencies had to emphasize training personnel and institution building activities especially for higher education. Most of the other intergovernmental organizations, as previously pointed out, are centered in Europe. The nongovernmental international activities do not as a rule undertake research directly, and the limited functions of keeping professionals in contact through conferences and committees excludes many of the developing and less-developed countries, but not intentionally. These countries simply do not have professionals in the first place or the ones they do have do not have the necessary resources to attend the conferences.

A consequence of this lack of participation is that opportunities to maintain close international scientific links are lost to those nations. However, a potentially far more serious consequence may be the lack of recognition and "secondary status" which the scientists of these countries tend to have in these organizations. Steven Dedijer has referred to this as underdeveloped science in the underdeveloped countries.[5] Some aspects of this status differential are considered in section II.32, Manpower and Training.

The tendency for the developed nations to be more or less self sufficient in science and to look to each other for inspiration is probably operative in the formation of so many regional and specialized organizations in the developed countries, which by location, definition or statement of objectives exclude the developing and less-developed countries. However, to offset this concentration of scientific activities, the developed nations have devised a variety of institutional arrangements which are designed especially to cooperate with emerging countries. Efforts along these lines include science as a part of wider goals for economic and social development. However, this tends to lead to the inclusion of political goals and as one consequence a great proportion of this help is given on a bilateral basis, i.e., the U.S. Agency for International Development, the British Commonwealth programs for collaboration and French assistance in Africa to former dependents.

Thus all forms of assistance whether scientific, technical, or economic flow through a great and increasing variety of organizations. This very diversity is a challenge to a balanced input of technical assistance to a given nation. Furthermore, the nations themselves have added to the difficulty of digesting this assistance in an orderly manner. Their organizational structure has grown so that they initiate requests for and accept assistance at many points in the country on a non-coordinated basis. All too often, this leads to a duplication of effort, waste, frustration and termination of efforts before goals are achieved. This is a general tendency due to the state of the arts in international cooperation, and many emerging countries have taken steps to avoid this difficulty in their own economies. Still, the redundancy in the international network, however necessary to reconcile needs of individual nations, remains as a very real constraint on the efficient utilization of the assistance available.

Duplication of effort occurs for another reason in advanced fields of technology. While traditional techniques of long standing usage in developed countries can be as readily transferred as the discoveries of basic science, exchanges of advanced technical developments for new processes and products are constrained by proprietory interests of countries and companies. The argument is put forth many times that the underdeveloped countries need only the traditional techniques in this phase of their development. If this is the case, the lack of easy access to advanced technologies is unimportant. However, it has yet to be demonstrated that the course of development must inevitably or even most of the time follow this pattern, and advanced techniques may be equally or more important than the traditional ones.

The diversity of organizations and conflicts in basic interests of various groups might not cause so much difficulty if cooperating nations had a sufficiently clear set of criteria to guide participation in international scientific activities. The problems of whether to participate at all, and if so, to what degree and in what fields and on what projects are all difficult to solve without this criteria. Also, while it might be relatively easy to formulate a plan for cooperation along scientific lines, this plan may have to be substantially revamped in terms of economic and political considerations.

In short, the full significance, potential benefits, and resultant complex involvement are just now beginning to be fully realized in the advanced as well as emerging nations. Every aspect of scientific activity whether it be forming objectives, deciding policies, designing plans, or building infrastructures must take international factors into account. In the ensuing analysis these factors will be pointed out, whenever relevant.

> "By far the most important issues the developing countries have to face is the shortage of scientific and technical personnel, particularly at higher levels, because the pace of progress in the organization of scientific research and development will be determined by the progressive availability of such personnel."
>
> _________Dr. Saliemuzzaman Siddiqui[1]

> "Manpower resources is hardest to acquire yet longest to endure."
>
> _________National Science Development Board and Higher Education, Philippines[2]

II.32 Manpower and Training

II.321 Major Manpower Problems

The gradual growth of science and technology in the western world obscures the enormity of the task facing developing countries which are attempting to advance scientifically for the first time. Nowhere is this difference more apparent than in the process of acquiring and utilizing scientific manpower. An entire new set of internalized values and professional standards must be acquired by these new scientists and technicians. The process extends further; in time, large elements of the entire population have been or soon will be exposed to technological innovation in some form and their habits and attitudes will be subject to change. The complexity of this process is only understood in a rudimentary way through studies such as Margaret Mead's Cultural Patterns and Technical Change.[3] Still, it is this relatively unknown interface that must be confronted sooner or later in any study of manpower, for it is the source of difficulty at two critical points in the development of scientists and technicians. First, almost by definition, a non-scientific culture does not have a high status for the scientists in its hierarchy of values or systems of personal rewards. Even in those countries which have realized this and taken steps to correct it by statutes that provide job classifications, promotions, tenure, and higher salaries much like existing civil service systems, the community as a whole is not aware of this upgrading. The consequence of this is to place a severe restriction on the free choice of science as a career by young students. Secondly, trained scientists and engineers tend to migrate to other countries where the environment is more conducive to the pursuit of a career in science (see section II.3212 following). It is not usually a neighboring undeveloped country but in all likelihood a more advanced nation. Potential scientists being trained abroad at great expense also tend to migrate, thus compounding the difficulty. In short, the process of acquiring and holding trained manpower is constricted at both ends. Regardless of these two problems, it still remains for a country to determine and fill existing and potential manpower requirements with remaining resources, or to take steps to decrease the likelihood of loss through migration or failure to return after education abroad.

II.3211 The Status of the Scientist

Two distinctions are important at the outset. First, the status of the scientist must be considered from two viewpoints, i.e., the scientific community and the broader culture to which it belongs, for the scientist is a part of both communities. In fact, it is not uncommon for the scientist to live in two contrasting worlds simultaneously; the world of the laboratory where he reacts and grows in a modern scientific context, and the world of his native culture which he shares with his family and which is bound by non-scientific or pre-scientific traditions. Secondly, it is important, just as in economics, to distinguish between development and change, with development implying organizational changes, changes in the quality and quantity of resources and structural changes, i.e., in stages of economic development. In contrast, growth implies a quantitative change within a structural continuity, i.e., it is one thing to add a scientist or technician to an existing laboratory and quite another to send him to establish the laboratory.

In the case of the first distinction, the scientific communities of emerging countries exhibit many common characteristics. Stevan Dedijer observed the following pattern in the many emerging countries he visited and considered it more or less typical. First, scientists are few in number and often dispersed over long distances. This isolation reduces interaction and mutual stimulation. Many times they lose contact with the international scientific community. They feel peripheral and out of touch unless they are able to visit and be visited by important foreign scientists. They feel inferior and neglected since their journals and publications are seldom read or quoted by foreign scientists. Moreover, they have little contact with scientists in neighboring developed countries. Not being full-fledged members of the scientific community their work suffers. Within their own country they often have poor relations with the political order.

Parallel to this isolation of the scientific community from international science and other scientists at home which Dedijer has pointed out is the isolation of the scientific community from the rest of the nation. The low visibility of the researcher is due primarily to his small numbers, dispersion, and the usually non-controversial nature of his work, i.e., it is generally not newsworthy in popular publications, accounts for much of this isolation. Also, science is a relatively new development for most of the less developed countries, most of them have a high rate of illiteracy, a small middle class, few schools and little industry. In essence, the channels by which the scientists is becoming known are new; it is a weak network with a small signal. It is a problem of low status due to a separation of the scientist from the mainstream in the life of the nation. He must compete for status with individuals already established in traditional power structures, i.e., the military and the government bureaucracy. Most of the time their education covers science in a cursory manner and stresses the social sciences, and humanities. The result of these conditions and the forces maintaining them is usually a low reward structure for the scientists professionally, economically, and socially. As a consequence, "scientific careers do not offer attractive prospects for talented young men, most of whom are at present drawn towards secretarial and administrative services" (Siddiqui).[2] For those who do select science, there is the constant search for identification professionally and socially. This reaches its most acute stage when scientists and engineers leave the country to work elsewhere. Equally important are the adverse effects of these conditions on the productivity of those scientists who remain.

The foregoing cannot be considered an accurate picture of any one country; rather it is a stereotype of a set of trends found with varying emphasis in most underdeveloped countries. Many countries, aware of the importance of science to their growth and development, are working to overcome these barriers. Also, there are many factors effecting this pattern either accenting or alleviating the conditions which isolate the scientist. One of the most important is the second distinction mentioned at the outset, i.e., the stage of development of the scientific capability. Since most of the emerging countries are at early stage of development, a proportionately higher share of the budget for scientific development and the efforts and the e ergies of the scientists must be used in just establishing the capability. However, a pioneering spirit may or may not be in the make up of the aspiring scientist. In any case, this preliminary stage is primarily centered on non-scientific activities. It is more than building facilities; it is nothing short of establishing the whole network of scientific contacts with the rest of society. The important thing to recognize is that it requires certain talents to engage in these non-scientific activities or at least patience to understand and accomodate to this situation. A lack of these attributes or abilities may considerably reduce the number of those who will consider science as a career or cause those who have been trained in science to migrate. At a later stage, as obstacles are overcome and institutions established and expanded, it is easier for a student to identify with a career in science at that time; he is dealing with known parameters in terms of his personal career, i.e., the "personal entrance fee" is lower. In terms of the trained scientist, it is more and more possible, although on a small scale, to concentrate directly on scientific research work with an established institution and to be rewarded and recognized by both the scientific community and the nation.

Cognizant that the establishment of a scientific tradition is more than training and equipment and becoming aware of the emigration of scientists, the developing countries themselves are using and/or advocating certain measures designed to improve scientific careers. These measures are designed to approach the problem from either of two directions, i.e., those aimed at creating a science-conscious public and those designed to improve scientific careers. These are to some extent overlapping but in any case reinforcing in overcoming the isolation and lack of acceptance of the scientific community. These measures range from observations to normative declarations and statements of intention. They were selected somewhat arbitrarily from the scant literature available to illustrate in more specific detail the problems clustering around any considerations of the status of scientists in developing countries. They are not presented as presumptions for action, and are not ordered according to any preconceived notion of relative importance.

(1) Measures to create a science-conscious public.

(a) "Governments have a great responsibility in organizing (through their various departments) and in financing the process of the implanting of science awareness in the public. The services of specialized bodies may be required as well as the provision of governmental staff for this purpose." (UNESCO Lagos Conference, 1964)[3]

(b) "The reasons which advise a more regular distribution of the research organizations in the national territory according with the general program of natural development, are many. Each scientific research center, for example, stimulates the surrounding society, employing the local manpower, which can be professional improved working through the tasks joined with researchers." (Quaranta, 1963)[4]

(c) "It is also important to draw persons from all social levels, so as to find a sufficient number of those who have good turn for the requested researches, and who can be trained quite easily and with no high cost." (Quaranta, 1963)[5] **

(d) In the educational sphere, much can be done to channel large numbers of students into science at an early stage. The idea of science should be introduced at the primary school level." (UNESCO Lagos Conference, 1964)[6]

(e) "It is important that all gifted children with the required intelligence rating should have an opportunity to be introduced to the study of science. This requires a conscious approach to the organization of science in education." (G. B. Gresford)[7]

(f) "At the university a conscious effort must be made to ensure that the student understands the importance and excitment of a career in science." (G. B. Gresford)[8]

(2) Measures to improve scientific careers.

(a) "A clear chain of command should be established allowing promotion by stages from a research officer to senior research officer to principal research officer." (UNESCO Lagos Conference, 1964)[9]

**Note: This is potentially one of the most important measures especially since it frequently happens that only the upper classes can now afford to give their children a scientific education.

(b) "It is necessary to differentiate between careers wholly in research (in research institutes) and in university teaching (involving both teaching and research). Clearly, the profession of the university teacher is already well established and a new statute is needed in Africa for the research worker working at the research institute." (UNESCO Lagos Conference, 1964)[10]

(c) "In most parts of the English speaking world, it has been usual in the more developed countries to insist on a first- or upper second-class honors degree as being the only entrance qualification for the would-be research worker but, as this may be too restrictive, it may be reasonable in Africa, at least in the early stages, to permit admission to graduate with minimum university qualifications if they can prove their ability at research." (UNESCO Lagos Conference, 1964)[11]

(d) "It is important that the merits are recognized primarily on the achievements in research made public to the scientific community of the world." (Massao Kotani)[12]

(e) "Invitation or employement of active scientists from abroad may give much stimulus to the promotion of scientific activities particularly in the field where few scientists are available at home." (Masoa Kotani)[13]

(f) "Scholarships, fellowships should be provided and national honors such as Academy Prizes should be rewarded to outstanding achievements in science." (Masao Kotani)[14]

(g) "Establish salaries adequate to attract and retain the nation's best minds in science and technology. A mechanism that might assist in accomplishing this would be the award of research grant support to the individual on a competitive basis that would supply salary supplementation in amounts sufficient to enable competent men and women to devote full time effort to research and teaching." (Cento Survey, 1963)[15]

(h) "Provide competent and productive young scientists with an effective voice in developing and implementing science, technology, and academic policy." (Cento Survey, 1963)[16]

These references indicate a number of sources of difficulty, many of them pointing to problems in themselves of interest and needing further study. More important, taken collectively they indicate the rudimentary state of our knowledge about the status of the scientist in developing countries much less how to improve it. However, its importance cannot be underestimated if science is to become a viable force based on indigenous scientists in developing countries, and this seems to be the premise on which most countries operate.

"The most effective safeguards against a steady osmosis of talent are to be found in vigorous leadership in the less developed countries and in the conscience and loyalty of the individual scientist. However, there are certain administrative measures which can help.

________ Nigel Calder[1]

II.3212 The Migration of Scientists

There are some indications that no matter how a nation improves its climate for the development of science it will only partially succeed in today's world. The combination of what H. D. Laswell refers to as the emerging international culture;[2] the growing economic gap between the "haves" and the "have nots" and the huge R & D efforts of a few nations, especially the United States, may set up sufficiently strong "pull" factors on a world wide basis such that only restrictive measures may ultimately be effective in retaining scientists.

The importance of the emerging international culture to the scientist is more than the opportunity to share professional experiences. Science has always been an international language, and most frequently the outlook of a scientist is world wide at least professionally. The emerging international culture is making this commonplace thus further reducing the barriers to keeping the scientist at home. Laswell indicates that the evidence for this international culture falls into three categories, all of which are applicable to the scientist:

(1) "indications of parallel patterns in national or sub-national communities (e.g., the teaching of modern science);

(2) indicators of trans-national flows of people, signs (media), and things (e.g., travel, communication, trade);

(3) indicators of trans-national perspectives (e.g., group identities, value demands, expectation)."[3]

The increasing gap in terms of CNP is commonly recognized, but the "R & D gap" is only now being realized. The huge sums that the United States has poured annually into R & D have become an international magnet to scientists:

> "From West Europe - mainly Britain and West Germany - in the years from 1952 through 1961, there flowed to the United States some 30,000 engineers, 14,000 physicians, 9,000 other specialists. The flow has speeded up since that time."[4]

But Britain and West Germany hardly fall in the category of developing countries. This is precisely the point, the flow is world wide affecting all nations. Steven Dedijer, on the basis of a questionnaire to about 400 scientists in 60 countries, noted the following trend.

> "The migration of scientists has certain preferred direction: from the less developed to the more developed countries, from countries developing slowly to countries developing rapidly, from small countries with developed science to large countries with developed science, and, most important, from countries with less developed science and education policies to those with more developed ones."[5]

For the less developed countries this migration, while applying to trained scientists, is more likely to take the forms of a migration of potential scientists. The seriousness of this migration is indicated by the estimate that 50% of all CENTO region scientists trained abroad do not return to their homeland or return and then secure positions abroad.[6] In India, this migration has also reached significant propositions:

> "According to the National Register of India as of July 1963, there were at least 8,000 scientists, engineers and physicians studying and working abroad without any indication how many of them are

permanently settled there. This amounts roughly to between 10 and 15% of all the scientists, both students and professionals, of India."[7]

The loss due to expenditures on training these scientists is obvious. However, the loss to their individual countries in terms of what they might have contributed over a life time of work not only in their respective fields but as part of the leadership necessary to develop the economy is probably much greater and more serious. Still, we know very little on the subject. Dedijer received the following reasons for migration in his recent questionnaire; in order of importance they include:

(1) low salaries, lack of resources for professional work;
(2) poor socio-psychological conditions for professional work;
(3) poor chances for advancement and promotion;
(4) lack of professional employment.

While this ordering is undoubtedly subject to variation depending on individual circumstances the same recurrent themes were found in the reports collected in the preparation of this paper. Some of them are included in the following list:

(1) "The reluctance of the highly trained young scientist from an underdeveloped country to return to his own country upon completion of his training....in many cases is motivated, at least in part, and in some cases it is entirely motivated by the knowledge that it is difficult to do good research in their own countries. Not only is equipment and financial provision incomparably poorer than it is in the advanced countries, but scientific administration is usually far more bureaucratic and antipathetic to the needs of scientists for freedom from petty controls" (Stevan Dedijer).[8]

(2) "Young scientists are deprived of an effective voice in developing and implementing the critical policies for research and education in universities and research institutions" (CENTO Survey, 1963).[9]

(3) "Promotion in academic and research positions is limited and frequently based upon retirement of older men rather than upon teaching and scientific accomplishments" (CENTO Survey, 1963) [10]

(4) "Positions available for young well-trained scientists and technologists are either limited in number or non-existent" (CENTO Survey, 1963)[11]

(5) "The salaries and status available to younger scientists are inadequate to support them and their families, which results in their undertaking additional employment and devoting "part-time" to their university and research endeavors, or, worse, leaving the fields of science and technology for more lucrative employment" (CENTO Survey, 1963).[12]

(6) "Many petty frustrations exist to the conduct of research which could be removed with great encouragement to the scientist:
   (a) "One of the major impediments is the deficit of adequate supporting personnel - technicians, librarians, clerks, and secretaries - a deficit directly attributable to the inadequate salaries paid to these occupations.
   (b) "Difficulties and unnecessary delays in procurement of essential equipment, or replacement of essential parts and supplies.

(c) "lack of adequate recognition of productivity in research" (CENTO Survey, 1963).[13]

(7) "The very fact that so many able scientists and engineers from the less developed countries go for part of their training to highly-developed countries exposes them both to a realization of the difference in facilities and to offers of employment" (Nigel Calder, 1963).[14]

(8) "The importance given to the different researching fields varies greatly in the developed nations in comparison with the importance they have in the emerging nations. Researchers may acquire estimation of the different scientific fields contrasting with the interest and the general program of scientific research in their own countries" (Quaranta).[15]

II.322 Determining Manpower Requirements

So far we have been considering obstacles to the choice of science as a career and the reasons for the migration of those who have chosen this career. It still remains to determine and fill the scientific manpower requirements of the country. This might seem by comparison relatively straightforward, but here, too, problems arise which complicate the process. In fact, all resources and constraints considered in this paper, manpower is perhaps the least predictable and controllable. This is due in great part to the nature of the task. Countries are attempting to know in advance what their requirements will be in several dimensions, i.e.,

> "For the program to be consistent, the demand and supply of scientists and engineers must meet each other, for each discipline of science, for each level of training, and for each period of time." (Masao Kotani, 1963)[1]

To accomplish this, developed countries can use the techniques of extrapolating current trends, but even here the indeterminant nature of how science evolves makes planning difficult. To some extent the developing countries can also use the techniques of extrapolating current trends, but even here, and certainly among the less developed countries, they are required to predict from non-existent or embryo facilities to an uncertain future without guidelines from the past. Secondly, the process is extremely long term: the development of a scientist begins in grade school and continues through graduate work.

In developed countries, the accumulated manpower pool; the vast net work of specialized institutions for training; and the established markets as well as several institutionalized factors combine to make the training process somewhat automatic and self correcting. Still, these countries are caught up in making manpower projections and plans to meet them. The process is much more self conscious and urgent in the developing countires. However, offsetting this to some extent are certain "advantages" inherent in their situation. Most important is the very existence of the accumulated wealth of scientific resources available in the advanced countries, if they can be effectively utilized. Among the alternatives which immediately occurs, the most obvious and often employed is the use of foreign experts. Also, work can be contracted out to advanced countries; a technique which seems to be one of the least exploited.

However, sooner or later the aspirations for an indigenous scientific capability have nations unsatisfied with too much dependence on outside sources, and most of them embark on a course which emphasizes developing their own manpower. Each country presents a set of problems and tentative solutions which to some extent is unique, but there are common trends in their programs.

One of these is the tendency to concentrate on higher education at the expense of technical education at the lower levels. This was more evident when training was so heavily dependent on foreign universities. It was considered feasible and necessary to make the large expenditure required for a chemist or a physicist but not a glass blower or machinist. As more scientists and engineers have been trained and as more indigenous institutions are being built or expanded, the question of what level and what skills to train is urgent. Still the lower levels are generally ignored. A recent survey (H.R. Mills)[2] of ten Asian countries revealed that,

> "in many low-income countries there appeared to be too much emphasis in the educational program on university training and not enough on the training of foremen and skilled workers."

An imbalance can occur in the opposite direction and frequently does. For instance, in comparing the ratio of technicians to engineers graduated in Chile and the United States in 1959, the following differences were noted (General Electric Survey)[3]

	Chile	United States
Technicians	1,500	20,000
Engineers	226	36,000

Inasmuch as it appears that the ratio of technicians per scientist is increasing, it is important to not only achieve an appropriate current balance but to take into account future trend changes. For instance, a recent study[4] conducted in the Netherlands shows that the ratio of craftsmen to engineers have been continuously rising:

	Number of persons with crafts per intermediate technicians	school diploma per engineer
1900	30	12
1930	25	36
1955	17	64
1980 (estimated)	13	50

Some of the current imbalance in training programs stems from a lack of a clear cut understanding of just what these levels are, let alone what they are to do. This results in wasting the talents of more highly skilled workers in routine tasks. One of the possibilities open to developing countries is to structure staff arrangements in accordance with this hierarchy. Prevailing lower wages makes it possible to use large numbers of technician per scientist than in developed countries where there is little wage differential. There are indications that this is receiving increased attention:

> "The organization of the more efficient research staff has a pyramidal form, where a base of a technical staff supports a better skilled technical personnel with an always decreasing number of persons. Only in this way is it possible to avoid the employment of persons compelled to accomplish tasks for which they have plentiful competence. For better research results and less waste, it would be necessary for no scientist to be compelled to work, for a certain time, through an activity that can be perfectly accomplished by less skilled researchers or simply by technicians." (Quaranta)[5]

The awareness of this problem of skill ratios, but also the current lack of concrete knowledge on the subject, is indicated by the statements made at the recent Lagos Conference sponsored by UNESCO on the Organization of Research and Training in Africa in Relation to the Study, Conservation, and Utilization of Natural Resources. The view was expressed which conflicts with the preceding notion of a pyramidal form, ie,

> "It appears that for a number of fields of research related to the natural resources a ratio of 1:3:2 between the three groups of workers mentioned here (senior scientists, junior scientist, technician) will give a fair estimate of the distribution of research workers between the various levels but this distinction will differ rather widely according to the field of research, and in particular applied research which involves more technicians."[6]

Professor V. Kovda of the Department of Natural Sciences at UNESCO, notes a pyramidal form but indicates that much higher ratios of technicians are necessary than considered at Lagos. He uses the classifications of scientific administrator, leaders of national scientific schools, research personnel and technicians, and states that the ratios between these groups based on experience in the scientifically advanced countries are as follows:

Scientific Levels	Ratio
Scientific Administrators to Leaders of National Scientific Schools	1:10
Leaders of National Scientific Schools to Research Personnel	1:30-50
Research Personnel to Technicians	1:300-500

In any case, the conflicting opinions and the sparsity of information available indicate the need for concrete studies in this area. In closing, one vital factor should be mentioned; the ratio between basic and applied research and development will directly effect these ratios resulting in more technicians being used the higher the ratio of applied research and development to basic research. Even with incomplete and sometimes inaccurate information, it is necessary to take action to fill the perceived manpower needs, if not the optimum balance based on all relevant considerations. It is to this problem that we turn next.

II.323 Filling Manpower Requirements

The desirability and extent of national planning for manpower may well be argued. However, to the extent that diverse organizations and institutes contribute to the development of these resources, coordination of these efforts will aid in minimizing duplication of some activities and omission of others. Where national research organizations exist, they are usually charged with this responsibility. An example of how extensive this cooperation can be is evidenced by the CSIR (the Council of Scientific and Industrial Research of Pakistan) which located its various laboratories in close vicinity to university campuses. This clustering of research facilities where resources are limited may be one successful approach to establishing scientific research communities.

In any case, the relationship of research institutes, whether private or government sponsored, to the universities is of basic importance because of the training possibilities it offers graduate students and recent graduates, and the increased relationships that are possible between university faculty and institute staff. This question of relationship between various institutions, but most especially between universities and research institutes gains added significance when we realize that these institutions are, in many cases, still in the planning stage, i.e., it is not so much a matter of changing as it is one of establishing policies and procedures. While the role of the university is quite clear, only recently has the research institute and its complementary function in educating specialists become clear, especially in providing the final phase of the research worker's training. In developing countries most of the research institutes will be of necessity government financed and usually government operated. Industrial firms are also a source for training but with recognizable limitations due to proprietary interests.

For the most part, however, training will be done primarily in specialized institutions or as part of the basic educational system of a nation. In fact, it is generally felt that it must be taught this way, i.e., "the problem of attracting and recruiting scientific personnel is bound up with the more general one of the reforms of education. . . .we cannot hope to solve the problem of quality instruction unless we make science and the scientific method permeate education as the social sciences and the humanities have acceptedly done." (National Science Development Board, Philippines)[1] This approach emphasizes the need to teach science as process not a set of rules; as a pervasive influence in the life of the individual not a set of isolated techniques.

In training scientists it is generally taken for granted that a proper scientific outlook will develop once the facts are known and the students have been initiated to the techniques of experimentation. While this may be justified to some extent in advanced countries which have a tradition of science, it is not necessarily so in developing countries.

One of the dominant needs of the training programs in developing countries is the need to conserve resources. One means of doing this is to impose realistic standards of selection which will minimize the high attrition rates, i.e.,

> "The increase in number as well as the fact that a large number fail or cannot complete the course taken, suggests the need of selectivity and direction in channeling students to courses based on their aptitudes (A. Rahman).[2]

> "It is high time indeed that we help to impose even in our public schools and state colleges so that we can thus spend wisely on deserving potential resources, and at the same time guard with care and proper respect, the resources of our training officials, the teachers in these schools (UNESCO Conference, 1964).[3]

Training, for the most part breaks into two broad classifications, i.e., technicians and scientists, including engineers and scientists and defining the latter group as those requiring a college education or better. As previously mentioned manpower needs for technicians are often neglected, yet provision for their development is perhaps even more important in developing countries. This was recognized by the CSIR in Australia in its attempt to industralize:

> "The provision of adequate university facilities for undergraduate and research training are essential pre-requisites in providing trained scientific manpower. Equally important is the provision of technical training for ancillary staff."...."in countries where there is little industry the problem is all the greater, it is even more necessary to make a conscious effort to provide such staff as

there is a smaller reservoir of technically conscious raw material than in countries having well established industires."[4]

The influence of the Australian experience has been felt in countries belonging to the Columbo Plan and is to varying degrees applicable to the situation in many other developing countries. H. R. Mills undertook a survey[5] of training facilities at the technician level in South and South-East Asia for the Columbo Plan Council. He concluded that some of the main technical needs were as follows:

(1) "More should be done to enable craftsmen to become technicians.

(2) "The status of technicians should be raised to make employment of this kind more attractive to secondary school leavers.

(3) "An apprenticeship system should be developed.

(4) "Greatly increased use could be made of facilities within underdeveloped regions.

(5) "Training aspects of the assignment of experts should not be overlooked."

Although stated as prescriptions, they are an indication of some of the needs generally prevalent in providing for technical education.

Turning briefly to higher education, it is generally recognized that a primary function of a university is to provide a flow of trained scientists competent to work in laboratories or educational fields. However, inadequate or insufficient university facilities may be the first impediment to providing a flow of trained scientific manpower. The greatest deficiency is usually in the staff itself, seldom is it highly trained and well rewarded. This puts into sharp focus an immediate problem: Is it more advantageous to establish or improve facilities and train at home or train abroad? Of course, some reasons for following either course of action are dependent on the research objectives of the country and/or institute. Also, it is not an either-or decision; both alternatives are used simultaneously and with varying emphasis, and each course carries with it certain costs and benefits. For instance, the following argument is given for graduate schools in Greece:

> "The establishment of graduate schools is necessary in facing long term problems. Greece will have to become more self-sufficient scientifically. The establishment of Graduate Schools will also lead to the establishment of a scientific tradition and atmosphere, the existence of which is indispensable not only for the country's economic development but also for the improvement of present efficiency in education and scientific research (OECD, 1964).[6]

On a strictly cost basis, in the short run, it may be cheaper to educate scientists abroad. A recent study in Greece (OECD, 1964)[7] indicates that it costs 150,000 drachmae, per person annually, not considering the cost of Greek scientists who do not return home. To train the same people in Greece, it is estimated would cost from 200,000 to 300,000 drachmae. Certain marginal advantages accrue for teaching at home. For example, some of the training cost can be directly transferred to agricultural and industrial research; foreign currency is saved, and the undergraduate school is upgraded as a result of an affiliated graduate school. A reasonable alternative is possible by training a research scientist at home in the early stages while leaving his doctoral program for study abroad. One important feature of training at home, that cannot be overlooked, is the possibility of attuning the program closer to the needs of the country.

Naturally, developing countries vary greatly in their educational facilities, but one of the most important distinctions is the difference typified by Latin America and Africa. In Africa, many new countries are just establishing universities for the first time, or, at best, are starting with an embryo faculty left from colonial days. In contast, Latin American countries have a long tradition of education dating back as much as four hundred years to colonial days. Education was traditionally centered in the humanities and non-technical areas. This, coupled with the decentralized organization structure, makes the introduction of science more difficult, i.e., the separate faculties control their own programs and consequently develop duplicate facilities. In short, the contrast is between institution building within the constraints of an established organization and starting practically "from scratch."

Further concentration in the problems of manpower might deflect us from a balanced presentation of the resources and constraints relevant to establishing and expanding a scientific capability in a developing country. However, the importance and complexity of the problems to be overcome has justified this emphasis on manpower.

II.33 The Flow of Scientific Information.

In contrast to scientific manpower which is a scarce resource, scientific information is an explosively abundant resources -- if it can be tapped. Of all the resources and constraints considered in this paper it is the one which is most often recognized as the resource available to developing countries from the scientifically advanced nations. A familiar argument runs that these emerging economies can either use the information directly or can readily adopt it and many decades of trial and error can be avoided. Underlying this argument which in itself is tenuous, is the assumption that there are adequate channels of communication in operation between the sources of information and the users; that information requirements are known, and that they can be met. When considered along these lines, hopes for an immediate and massive flow of information assume more realistic proportions.

When one considers the flow of information from the scientist to the ultimate user, there is even less ground for a simplistic approach to the problem. Whereas the scientist or engineer is trained to use and search for information sources, ultimate users of the products of science are not necessarily so equipped. It is clearly recognized that these are topics in themselves worthy of large-scale studies, such as current research at Northwestern University in the Programs of Research on the Management of Research[1]. However, more needs to be known about these topics from perspective of a scientist in a developing country.

II.331 The Information Flow to the Research Worker

The information requirements of scientists in a developing country can be considered from two perspectives. One is the viewpoint of a scientist who is working in an advanced field of research and contributing to the world body of knowledge such as arid zone research in Israel, geo-magnetism in Ghana, and geo-chronology in Brazil. A second group of researchers are working in areas where there is more of a uni-directional flow of information. For instance, vast fields of industrial and agricultural technology which are not controlled by propriety restrictions are available, in addition to the information available through formal licensing agreements. Some of this information can be used directly; more often it serves as the basis for adaptive research, i.e., techniques which require some modification before being integrated into local production systems. The Stanford Research Institute in particular has emphasized the need for this adaptive research as a result of their studies in developing areas. (Staff Paper, Stanford Research Institute).[1]

The first group consists of a small but growing minority of the scientists in developing countries. Either by personal contact or institutional relationship these scientists are in effective communication with their counterparts in scientifically advanced nations. However, the primary focus from the point of view of this paper is on the latter group--the great majority of scientists and technologists that work in comparative isolation and are primarily "consumers" of technical information.

A variety of circumstances have prevented their needs from being met. As A. A. Sabet of the UAR Science Council points out:

> "In the field of documentation, the major difference between developed and less-developed countries, is that in the years of backwardness no learned, scientific or technical institutions--or very little, are established in the latter. In rare incidents, good libraries ever existed. Usually none or few mostly like, or behaving like, store-houses that could be mentioned. This, of course, is completely related to the political, social and cultural conditions which encircle these countries."[2]

A detailed examination of these circumstances is unnecessary at this point, since they are part of the complex of conditions prevalent in pre-scientific and transitional economies which were discussed under Manpower and Training, Section II.32. Once the initial realization of the need for and the importance of a network of information channels has been made, the problem becomes one of choosing which channels to develop. Of course, this is easier said than done due to the wide variety of channels available, as indicated in the following list:

1) Correspondence
2) Personal visits
3) Formal conferences
4) Exchange of scientists
5) Lectures and study tours by well known scientists
6) Regional scientific journals
7) Scientific societies
8) Technical assistance projects
9) Technical exchange programs
10) Commercial technical agreements
11) Documentation centers
12) Specialized information services.

Of these, documentation centers and specialized information services will be discussed very briefly to give some indication of some of the problems involved in information flow in developing countries. First, information services are becoming increasingly elaborate. Considering only a single profession, such as medicine in the United States, a complex taxonomy of information services can be developed.[3] These services can be considered at the international, regional, national and institute level, but a recent study on documentation in the Cento Region indicates the need to emphasize work at the international and regional levels:

> "It is not possible to remedy the local situation by improving individual libraries in isolation, although this is essential. It is necessary to work within both national and regional frameworks and induce the utmost cooperation between different libraries. In this connection it is disquieting to realize how few professional libraries there are in the region and even more to learn of the return of any of these to the West because conditions do not allow them to work efficently in the region."[4]

Within the nation, A. A. Sabet of the U.A.R. Science Council points out that the development occurs along two lines, i.e.,

> "From our experience in U.A.R., as well as in other countries, and world documentation trends, two kinds of services need to be organized: (1) one working on a national scale, (2) the other serving the particular institutions in every field of scientific knowledge."[5]

This observation seems to be born out by the number of nations which have initiated national documentation centers and also by the UNESCO program for documentation centers. One of the main functions of the national centers is to survey the scientific literature; but when the number of scientific journals is rapidly increasing, they are in danger of being overcome in a flood of information. Also, as the scientific capability of a nation grows, it becomes increasingly difficult to provide service to all users. On the other hand, specialized services run the risk of providing too elaborate a coverage and being too costly for the number of inquiries received. However, once the balance is struck between these two approaches in the initial network design, the current state of the arts in information and documentation is available for developing facilities.

At this point, problems of hand or mechanical retrieval systems, bibliographic indexes, storage facilities, cataloguing and so forth are relevant. Detailed disucssion of these is beyond the limits of this paper, but one point should be mentioned in passing. As more material is published in new languages, an already current problem will be greatly aggravated, i.e., the problem of furnishing expensive translation services. This problem is proportionately the greatest in those countries most removed from the scientific tradition of the West.

II.332 Flow of Information from the Scientist

The problems of the preceding section presuppose a scientific and technical community with information needs. Supplying these needs is by no means simple, but it centers on the problems of removing known obstacles and designing appropriate organizations. In contrast, the problem of disseminating information generated by the scientist in a developing country, assuming it is potentially applicable within the country, is not as easily approached. It is true that a few organizational forms such as an extension service are available, but the problem is not so much one of putting interested parties "in touch" so much as in stimulating an interest, sometimes for the first time, in ultimate users of laboratory results.

The flow of information is appropriately considered first in the broadest possible context, i.e., the cultural setting. After all, research results are another form of change to a pre-scientific society. Similar barriers and rigidities which keep a given society from progressing in other areas limit the easy dissemination of research results. Furthermore, the techniques themselves are not simply what they appear to be; in the words of Alain Birou[1] they represent

> "a socio-cultural crystallization of this society. In a pre-industrial country, techniques are therefore not important in the pure state but accompanied by a whole socio-cultural complex. This is why the historical forms of domination and the status and approach of experts are decisive factors in the harmonious integration of techniques into a society which must reorganize itself and create new socio-economic relations to be used rationally and profitably."

Although this observation is meant to apply to the pre-industrial countries, it also applies, although to a lesser extent to the developing countries, which are in what Rostow would call the "transitional" and "take-off" stage of development.[2] Many of these countries are developing with dual economies which have large pockets of traditional pre-industrial society.

Birou points out that for countries which are more or less passive objects of the "application of technology" the problem has several aspects affecting the nation and society as a whole:

> 1) "For a society to adapt new methods involving the intelligent, rational use of new instruments, it must have a certain capacity to absorb such methods and must fulfill certain prior conditions regarding the general level of education, knowledge and skill, social attitudes, systems of values, and forms of authority.
> 2) "The backwardness of non-industrialized countries affects the whole structure of society, which is still monolithic. This must be changed by the general reorganization of political, social and economic life. As the progress of institutions and systems is brought about by substitution, adaptation to the demands of modern activity will often be violent and spasmodic; it is almost inevitable that there should be tensions and conflicts between the various forces present."[3]

From these two observations many normative propositions could be made, such as Birou's that knowledge and know-how must be applied as part of an overall pattern of economic growth; that technical aid should be "integrated" co-operation, and that technical applications should be coordinated and balanced. Furthermore, projects should have a cumulative and multiplying effect to avoid technical bottlenecks, and to this end aid should be applied at key points or in key sectors.

The prescriptive ideas, as valuable as they may be, do not point so much to the <u>process</u> of introducing change as to its direction and emphasis. Birou makes a more relevant comment to the process of change when he points out that education through the application of techniques is as important as their actual application. In particular, he makes an appealing statement of the problem in terms of the role of the sociologist.

> "At a deeper level, it is the whole of society which is changing. This calls for deliberate action: a study of the structural reorganization required, the new institutions to be set up, the diffusion of new behaviour patterns, and the organization of the whole socio-economic system is absolutely necessary, with the science of sociology and its special techniques playing their part."[4]

It is useful to think of deHemptinne's model of a scientific network (see comments in section II.211) in conjunction with Birou's observations. It provides a basis for describing the structures to which he refers.

The interrelatedness of this process of introducing new ideas cannot be underestimated. As Dr. J. van Baal[5] points out, technological change is cultural change; it has to do with society as a whole and with man as a whole. From a technological point of view the problems are the same as in a developed country, it is the human problems which differ and require emphasis. In this context Baal is using the concept of culture" not as a more or less accidental complex of arbitrarily accumulated cultural elements, but an integrated whole expressing a certain way of life, a fundamental attitude shared in a greater or lesser degree by all the members of the society which produced that culture."[6]

In this context the core of the problem is that for technological change to be successful it must be the result of a change in man. It is easily possible to think of how many traits are necessary for success in a technologically advanced society such as punctuality and orderliness. But in turning the point around, as Baal suggests, is it possible to think of such a list which should be implemented in this restructuring of the personality of people in less developed areas? For Baal this is nonsense, the only productive approach he suggests is an examination of the local situation to find and correct deficiencies. How and to what extent this can be done is still little understood. It is only natural Baal and so many others turn to education as the panacea, it seems so much easier to effect change in the young. The considerations at the national level have been included to provide a backdrop to the more restricted problem of the dissemination of scientific and technological results from scientists to users in developing countries. It may well be that the only effective introduction of these results can come through a national apparatus or from a central authority, at least in the initial stages, but in any case, exchanges soon occur at the inter-institutional and inter-personal level.

Considering first the utilization of research results in industry, there are several reasons in addition to the general cultural factors mentioned above, that inhibit the utilization of these results. As K. G. Krishmamurthi points out, "laboratory-scale researches do not normally attract entrepreneurs in a newly developing country."[7] This means research laboratories must undertake pilot plant and even semi-commercial and commercial scale operations. The difficulties normally encountered in scaling up call for a higher order of skill and facilities than is usually available. Also, the needed parts and equipment can seldom be fabricated in one shop and must be imported.

Secondly, and perhaps more important there is a lack of effective methods for communicating research results. K. G. Krishnamurthi expands on this along the following lines:

> "There is a general lack of awareness of the problems and needs of each other both among scientists and industrial executives. Whatever liaison exists between them is meager. Dissemination of research results for the benefit of industry has to be specialized and should be very different from scientific publication meant for scientists. Similarly, publicity through mass communication media meant for the lay public is also limited in its usefulness, to some extent, information from scientific journals and also from lay publicity materials reaches executives in industry but practical results of utility in industry will have to be put across to them in specific forms and journals or communication media meant for this purpose should be oriented with this end in view."[8]

As with any generalized picture this may prove to be inaccurate when applied to a particular country, but it contains the essential elements of an almost universal deficiency.

A third factor is the hesitancy of entrepreneurs to accept indigenous research because of the risks involved in installation. They have become used to purchasing "turn-key" operations from abroad along with well established know-how. Fourthly, in the early stages of production, these companies do not employ scientists and technologists; this applies even to some of the largest manufacturing companies. As a consequence not only is it difficult to bring innovations into the operation, but, in addition, many opportunities for internal improvements in methods, products, and application are overlooked.

In an effort to bridge these gaps between obtaining and utilizing research results, several techniques have been devised or adapted from advanced countries. The better known of these adopted techniques include liaison and extension services, exhibitions, conferences, symposia, and publications. However, there are new organizational forms which are more directly a response to the emerging economies, i.e., the development bank and the development corporation. These are more likely to work in close cooperation with research organizations.

Whatever the problems encountered in the utilization of results in industry, they are dwarfed by the problems of implementation in the agricultural sector. Here cultural patterns are even more static and the people less receptive to change than in the urban centers. Yet this is usually where the majority of the population is concentrated so the problem assumes major proportions on this basis alone. Consequently, many attempts are made to set up an extension service in conjunction with agricultural centers and experimental stations using the U.S. Department of Agriculture as a model. Also, agricultural research is less costly to set up and maintain, on the average, than other forms. E. B. Worthington makes the following comparison:

> "The range according to subject is very wide, from under 2000 pounds in the case of sociologists who require little in the way of laboratories and equipment, to over 10,000 pounds in the case of the Desert Locust Survey, in which the scientist works far away from his base with a team of European and native assistants, a fleet of vehicles, wireless, etc. For research on agriculture, animal husbandry and fisheries, the average figure in East Africa is a little less than 4000 pounds."[9]

Many of the developing countries have one or more cash crops such as coffee or cotton which presents a sharp contrast to the indigenous, subsistence level sector. It would be more appropriate to consider these as "industries" due to the relatively high state of organization from the growing through the processing stages. While ownership patterns and the importance of the crops vary, the ones which have a significant impact on the national economy are likely to have either private or state supported research activities; i.e. coffee in El Salvador and tea in India, etc. In these cases, the research activity is closely coupled with an educational and extension service.

Specific examples of some of these foregoing factors are pointed out, where applicable, in Chapter III.

II.34 Investment in Research and Development

Only brief mention will be made of the problems of investment, since they are heavily contingent on the factors which have been previously considered. For instance, R & D allocations at the national level must compete with a host of other items in the national budget and as such are a part of national planning and policy consideration. The process of project selection determines and is determined by the amount and availability of funds. In considering the resources and constraints, international relations play a key role in determining sources of funds. A nation which has chosen to isolate itself from international aid programs as well as bilateral programs with, for example, the U. S. and Western European countries has an entirely different problem of funding than, say, India which is closely cooperating with the U.N., Great Britain, and the U. S. in a number of bi-lateral agreements. Also, the amount, availability, and quality of scientific manpower put an upper limit on the efficient use of funds.

Still, many factors relate directly to funding and a few should be emphasized. One of the most frequent observations made is the relatively high percentage of G.N.P. which the U.S., Britain, and the U.S.S.R. invest in research. The percentages scale down with a high degree of correlation as gross national products are lower and per capita incomes are lower with relatively few exceptions. For example, Dedijer notes that, while R & D expenditures in 1960 were 2.8 percent of G.N.P. in the United States, 2.3 percent in the U.S.S.R. and 2.5 percent in the United Kingdom, they were only 0.2 in Ghana, and0.1 in such countries as the Philippines, India, and Pakistan.[1] Consequently, this correlation is cited as a reason to invest in science and improve the G.N.P. However, no causal relationships have yet been demonstrated to support this contention. It is even reasonable to postulate that it is possible for a relatively undeveloped nation to invest two, three, or even four percent of its income in R & D and not improve G.N.P. This could happen for a number of reasons.

First, regardless of the causality between R & D and G.N.P., the countries with high R & D expenditures have a closely coupled system whereby R & D results are a direct input to the economy through several channels. For instance, industrial firms do their own R & D and government contracts for R & D are directly translated into space and missile hardware. In contrast, R & D in developing countries is often undertaken without assurance of utilization. As E. E. Worthington points out, "It is certain, moreover, that a great mass of valuable knowledge lies buried in departmental files throughout Africa, because the individual concerned had gone away and his successors have been too busy to analyze and produce the data in a form suitable for publication."[2]

Other factors regarding the utilization of R & D results were pointed out in the preceding section. Finally, and of great importance is the fact that ultimate users are not sponsors of R & D. In most developing countries it is the government which not only finances, but also controls and directs the R & D capability.

Secondly, the R & D effort may be a high percentage of G.N.P., but not for a sufficently sustained period. One of the most important factors in all R & D activity, is the relatively long time horizon in planning and long operating cycle in achievement in contrast with other activities such as production. Furthermore, when R & D is considered on a short term basis, as in the case of short term projects, they are done within the framework of an organization and with manpower which has developed over a long period. An example of this long term aspect of R & D and one which is especially relevant to the agriculturally based economies, is the research and extension service of the United States Department of Agriculture dating back to the late nineteenth century. This program was particularly known for its close cooperation between the government and the universities. Today the United States is experiencing a return on an investment of several decades.

A third factor of importance, when considering the national effort devoted to R & D as a percentage of G.N.P., is the absolute amount involved. Three percent of the U.S. budget results in a $20,000,000,000 R & D budget; three percent of the budget in several countries will only net $20,000,000. This is an order of magnitude difference of 1000 to one. In addition, in developing a scientific infrastructure in a newly emerging country, a disproportionate amount of the funds must go to administrative and support activity. Of course, this is not a phenomenon restricted to R & D activity; economies of scale operate to the disadvantage of the developing countries, especially the smaller ones, in the establishment of a number of activities, i.e., some government activities, such as the diplomatic service, which are not a function of population or size.

Fourthly, the R & D effort is liable to be fractionated, first, by departments competing for scarce funds and secondly, by individuals being assigned to too many projects for effective work. This is a danger in even the best planned operations due to the need to satisfy political considerations; i.e., the need for results to "make a showing." In fact, due to the poor linkage with users of R & D results and services, a disproportionate share of the funds might be used to make reports and to undertake "showcase" projects to "sell" the government sponsors of R & D activities rather than the ultimate users.

Fifth, we know very little of the growth curves of R & D activity; i.e., the dynamics of the situation over a period of time. In India, one of the few developing countries where scientific planning has been incorporated into the five-year plan (in fact India was the first developing country to do so), Dr. S. Husain Zaheer of the Survey and Planning of Scientific Research Unit points out:

"In cases where the rate of growth has been extremely slow and the area is of importance for national development, we have suggested a considerable quantum of investment in the remaining period of the Third Five Year Plan and also a particular rate of growth. The presumption which has led to the suggestion of such a course is that investment below a certain level is not conducive to productivity in research - it would only lead to scratching the surface, or tinkering with research, rather than produce serious results.

"The other considerations in suggesting the varying rates of growth are: capacity to absorb increased research allocation, level of development of the sector, relevance to national problem, availability or possible availability of trained personnel, technological level and technological requirements of the sector and other such factors.

"It may, however, be stated that none of the above problems have been studied and no quantitative data is available to make precise estimates."[3]

This last remark need not be restricted to India; few of the developing countries has yet devoted serious attention to the study of these factors. Thus, investment has tended to be made either as an extrapolation of experience a response to a particular department or individual, or as an echo of the national economic development plan. In short, on an ad hoc basis, for the most part. Again, a stereotype such as this would cause criticism in certain countries which attempt a systematic approach, but in the main it represents the state of the arts in many developing countries.

Sixth, it is important to recognize the stage of development of the scientific capability. Due to the relative recency of developing a serious scientific infrastructure, a higher percentage of the investment must of necessity be in building the basic units and training or acquiring the necessary manpower. It is not only a question of dispersing funds to going organizations; it is a question of establishing entirely new organizations. Worthwhile return on these activities may not occur for several years or decades.

A seventh point concerns the source of funds. A high percentage, even the majority of R & D funds may be acquired from foreign sources whether international, bilateral, or interinstitutional in scope. These funds (1) are not necessarily, in fact are not usually coordinated; (2) they are not permanent in nature; (3) they may reflect plans of the sponsoring agency which are not necessarily consonant with the development priorities of the nation. The result of this diversity of sponsorship may be to reduce the overall effectiveness of the funds with duplicate, overlapping, and marginal allocations. The result would be an over estimate of "effective R & D expenditures."

Eighth, comparisons with the United States, Britain, and the U.S.S.R. should take into account that developing countries do not have high military R & D budgets. As pointed out in section II.22 on Science and Economic Growth, a more realistic comparison might be to countries such as Australia, Finland, Canada, Iceland, and Norway in which G.N.P. depends especially on agriculture, forestry, mining, and fisheries; i.e., industries with a relatively low research input. These countries show a relatively low R & D expenditure in relation to per capita G.N.P., yet G.N.P. per capita in some of these countries are among the highest in the world.

Ninth, the nature of the R & D activity will be significantly different, depending on the stage of a country's development. Many problems requiring basic research in the study of natural resources are similar to infrastructure investments. These are likely to occur early in a country's development as contrasted with incremental investments which add to a relatively known course of development. This relates directly to the next factor, the element of risk.

Due to the smaller absolute amounts invested there is a tendency to invest in less risky projects. A research portfolio is somewhat similar to an investment portfolio in securities. Smaller total funds do not allow investment in the riskier but potentially higher payoff projects, at least, not when there is a simultaneous constraint to show some positive results in all cases.

None of the foregoing is meant to depreciate efforts to increase the R & D percentage of G.N.P., but only to put the use of these ratios into some perspective. One percent of the G.N.P. in all the developing countries of say, Africa, would probably produce widely varying results. All of the foregoing factors would influence the overall rate of investment, and beyond this at the micro or sectoral level much work needs to be done. As Dr. Zaheer points out:

> "We further suggest that once a broad decision for the quantum of investment in research has been taken in the near future intensive studies on the deployment of investment be undertaken, i.e., the relative emphasis on different sectors, the proportions within a sector and a more critical appraisal of research programs from the point of immediate and long range gains, have to be undertaken, to get maximum results out of scientific research."[4]

This concludes a selective analysis of certain resources and constraints; certainly others could be added. However, those discussed should give some indication of the forces which, in conjunction with research objectives, policies and planning procedures, shape the resultant research capability and help determine the research portfolio.

II.4 Science Research Capability

Research capability has already been defined as the potential existing in a country for the production of inventions and discoveries. In order to study these capabilities on a comparative basis, data is being collected especially by UNESCO; in addition, many countries are beginning to gather more extensive data for internal control as in India's Research Planning Unit. At this point, these statistics are too fragmentary to present an adequate picture of R & D activity in developing countries. For instance, the sectoral analysis used in the OECD countries, where statistics are gathered according to a breakdown by Business, General Government, Institutes of Higher Learning and Private Non-Profit Institutions, can be used successfully in countries such as Brazil and India. In less developed countries, distinguishable economic sectors are only now emerging let alone a supporting scientific infrastructure.

Perhaps one of the more useful approaches for understanding the unique characteristics of the R & D capabilities in developing countries is the institutional approach described by Y. deHemptinne in The Science Policy of States in Course of Independent Development and referred to in section II.21 on Science Policy. This approach consists of recognizing an operational network of basic components in the scientific infrastructure which have certain necessary, recurrent functions such as: training scientific workers, research operations, and scientific information. The advantage of this approach is that it allows an analysis of specific organizational structures which are emerging in developing countries while still maintaining an overall view of the operational networks in the respective countries. A statistical approach would not detect these organizational variations.

A good example of these new types of organization is the central research institute which has been established in many countries, i.e., Burma, Ceylon, Columbia, and Mexico. Ralph A. Krause describes the role of this type of institute as follows:

> "A central organization--designed to provide technical assistance to each segment of the economy, staffed with scientific and technical personnel, adequately equipped with laboratory and supporting facilities and suitably directed or motivated toward serving the Government, industry, and business of the country--can be a major asset in the development program."[1]

Similarly, A. V. Austin describes the role of a national laboratory and notes its value to a developing country:

> "An appreciation of the importance of the basic technical services that must be available for a growing technology, and which can be provided by national laboratories, is a starting point in extending technology to the less advanced areas."[2]

Accordingly, a somewhat similar approach has been developed by A. H. Rubenstein, the director of the long-range study, and the writer in which these organizational techniques, or strategies can be described. This was first attempted in <u>An Analysis of Alternative Strategies for Organizing the Applied Research Activities of Developing Countries</u>.[3] Then in order to describe the R & D capability of a nation, patterns were developed composed of these strategies in <u>Strategies and Patterns for the Organization of Applied Research in Latin America and South and Southeast Asia</u>.[4] A similar approach is used in the following chapter and will be discussed in greater detail at that point.

II.5 Scientific Research Portfolio

The subject of scientific portfolios, the actual R & D projects undertaken, can best be discussed in terms of specific country situations. On the otherhand, topics which can be discussed generally, such as project selection criteria (Pound and Baker)[1], are in themselves subjects for extensive analysis. Within the context of this chapter, it remains to make a few brief comments on the R & D portfolios in terms of the general model.

First, for R & D geared to economic development, it is important to note that local conditions impose a different portfolio emphasis due to differences in such factors as climate, topography, and the dispersion of resources. Climate alone causes entirely different clothing and housing requirements. Prolonged humidity causes early machine obsolescence and heavy maintenance costs. Intense heat poses problems of food storage, and scarce water resources limit agriculture. Arable land is often limited in many newly developing countries and the topography consists of mountains, desert, and jungle. Many of these countries have scarce fossil fuels and mineral resources and cannot establish basic steel and petrochemical complexes. Economies, in many cases, are based primarily on one crop or mineral resource. In addition, the developing countries are likely to have an abundant number of unemployed and underemployed people. Much of the industrial R & D in the economically advanced countries has emphasis on labor-saving machines and methods rather than capital-saving ideas making imported techniques less applicable. Certainly many of these problems are true of parts of more developed countries, but it is the overriding importance that one or more of these factors has in the developing economies that constrains the R & D portfolio geared to economic development. In fact, some observers, such as Jack Baranson,[2] think that whole new technologies will have to be developed if these countries are to support a population on a basis comparable to Western countries. In short, without belaboring the point, a whole new spectrum of problems ranging from basic theoretical problems to numerous practical applications in many major fields of science and technology are part of the R & D portfolios or programs of developing countries.

Whether an R & D portfolio is constrained by economic development considerations or not, a fundamental issue is the appropriate balance between basic and applied R & D. This is one of the perennial controversies in discussions of national science policy. Arguments are presented supporting many intermediate positions and ranging from an exclusive emphasis on applied research to a capability with a high ratio of basic research. Others consider the distinction between basic and applied research too limited and attempts, which were previously noted, have been made to define R & D in other ways such as "fundamental oriented" research by P. Auger.[3] In discussions of specific R & D strategies and patterns, the emphasis given to basic or applied research and to the various fields of science and technology will be noted.

III. SCIENTIFIC OBJECTIVE, STRATEGIES AND PATTERNS

III.1 Organization and Objectives of the Analysis

The existing literature on the R & D process in developing countries has, for the most part, remained in a monograph and report stage; and it is difficult to get an overall sense of this process in these areas. This is understandable due to the relative recency of significant R & D activity in the developing countries, and the fact that interest in this area has not been widespread, until recently, i.e., the United Nations Conference on the Applications of Science and Technology for the Benefit of the less Developed Areas held in Geneva in February 1963, and several regional UNESCO meetings for national science organizations. Consequently, an attempt has been made in the preceding chapter to bring some of this material together in the discussions of the general flow model.

Having generally defined the field of interest in terms of major problem areas, it remains to examine specific country objectives, strategies, and patterns along these lines in order to accomplish two further goals. First, the examination of these factors is in itself of value as an aid in understanding the unique and recurrent characteristics of these elements. As such, this provides a basis for comparative analysis. Secondly, by examining these elements in a systematic framework of analysis, a 'proposition generator' can be produced which will isolate major variables and their relationships for further study.

To accomplish this, "objectives" are collected and classified. The scheme of classification, although arbitrary, will make an initial formulation of major evaluation criteria, or guidelines, within which the degree of success, or goal attainment, of country patterns can be examined. Following this, selected organization strategies are analyzed in terms of basic dimensions such as method of funding and implementation. These strategies provide the basis for a general model describing country R & D patterns. Finally, since our information at this point is still fragmentary, several partial patterns are described which illustrate various levels of organizational development.

III.2 National Scientific Objectives

III.21 Collection of Objectives

Besides isolating variables and forming a basis for comparative analysis of R & D patterns in developing countries, the collection of objectives emphasizes the special point of view of developing countries. So often when these countries are viewed from the vantage of a scientifically and industrially developed society, the prescriptive point of view prevails and obscures the many aspirations that find their expression in development plans. From the beginning of the long term study of which this thesis is a part, an effort has been made to collect information in the form of annual reports from scientific institutes, national science plans and policies, and correspondence with leading scientists.[1]

In particular, besides the data collected by Pantin[2] and Adulbhan[3] on Latin America and Southeast Asia, the author of this paper sent a questionnaire and request for information to over 400 institutes and individuals in Africa and the Middle East. (Exhibits of the letters and questionnaires are included in Appendix A). The net result of these efforts was the collection of what appears to be a fairly representative sampling of R & D activity in the major developing areas. In addition, correspondence has been maintained, where possible, with individual institutes and scientists in an effort to up-date information. This collection of documents and questionnaires does not yet provide a basis for a rigorous comparative study, nor was that the intention at this point. It is this information which provides the basic source material for the objectives and strategies which are presented in this thesis.

Regarding the objectives, it is recognized that it is not possible to obtain either an accurate nor complete enumeration. Even the most detailed national science policy is only a partial statement of actual policy; it includes many "aspirations" of a non-scientific nature, some of which cannot or will not be translated into actual scientific activity. Nevertheless, it is felt that a wide sampling of these statements, whether of accomplished fact or of intention, would better define the parameters of the general model outlined at the outset than any other method at this point. Accordingly, a list of such statements was made and a rather extended illustrative list is included in Appendix B. These objectives were examined for recurrent themes and the results, in turn, were grouped in two major categories: (1) those which refer to the <u>utilization of the scientific capability</u>, (2) and those designed to <u>increase or improve the scientific capability itself</u>. The distinction is worthwhile, since many countries now emerging from a traditional cultural and even those advanced to the point of take off, require a greater relative effort on institution building and promoting science than do advanced nations where the benefits of science are already known.

These major divisions were then grouped according to several sub-headings. The actual statements of objectives have been reduced to shorter statements which include the major variables, while the source list of statements is included in the appendix in original form. The sub-headings were derived after the collection of objectives to avoid, as much as possible, the construction of an artificial system of classification. Some objectives included in the ap appendix were noted in previous papers related to this study,[4] Pantin's thesis,[5] and Adulbhan's thesis.[6]

III.22 Classification of Objectives

A. NATIONAL GOALS AND ASPIRATIONS

1. <u>Cultural and Social Development</u>

Stimulate, utilize, and promote R & D to attain
(1) cultural development
(2) human well being
(3) national security
(4) social welfare
(5) basic and immediate human needs
(6) high level of living conditions
(7) peace

2. <u>Economic Development</u>

a. Orient Research to Economic Development
Develop R & D related to economic development and progress
Emphasize R & D related to production
Increase the rate of technological progress

b. Discover and Inventory National assets
Accelerate scientific explorations to increase basic knowledge of biological and mineral resources

c. Increase Industrial Development
Develop R & D in primary manufacturing industries
Establish and assist R & D efforts for special industries
Utilize R & D to develop industries
Develop R & D to utilize industrial waste products
Utilize R & D to assist nascent industries

d. Improve Agriculture
Increase production of staple crops
Develop agricultural, food, and nutrition R & D
Develop R & D to utilize agricultural waste products

e. Improve Balance of Trade
Direct R & D of indigenous resources at reducing imported minerals
Direct R & D at upgrading and expanding exports.

f. Utilize Indigenous Resources
Utilize R & D to improve exploitation of fishery, forest, mineral resources, and water systems.

B. NATIONAL SCIENTIFIC GOALS

1. <u>Make Scientific Contributions</u>
Make worthwhile contributions to the international pool of scientific knowledge.

2. <u>Formulate Science Policy</u>
Promote, guide, and coordinate scientific and industrial research
Undertake research at the request of the government
Establish at the highest level, a body responsible for formulating science policy and coordinating research
Survey the scientific resources of the country
Formulate a plan for the maximum utilization of scientific resources in solving the country's problems

3. <u>Determine Portfolio Emphasis</u>
Emphasize applied research in solving short term problems
Examine both local phenomena, i.e., ecological, geological, and biological, and universal subjects such as the atom
Plan and execute projects emphasizing the long-range development of science
Encourage study in the pure and fundamental sciences
Utilize foreign know-how in the short run
Recognize the need to attain a proper balance between fundamental and applied research

4. Increase International Cooperation

Cooperate with government and private institutions in matters effecting applied research

Make contact and promote cooperation with research institutes and research workers abroad

Promote international scientific activities and cooperation

Cooperate at both the continental and regional level to solve common problems

Cooperate with foreign experts

5. Collection and Dissemination of Information

Develop, collect, publish, distribute and exchange scientific information with institutions of national and international status

Encourage the practical application of R & D results

6. Funding

a. Establish Research Funds

Attract funds from overseas

Allocate funds to R & D in the national budget

b. Allocate Fellowships and Grants

Offer fellowships to individuals and grants for research projects

Make awards to research workers

Allocate at least 80% of the long range Science Development Fund temporarily to natural sciences, and basic sciences in medicine, engineering, humanities, and social sciences

7. Organization of Scientific Activity

a. Provide Organizational Network

Strengthen and improve the organizational network needed for the implementation of national science policy

Establish and operate research institutes and other facilities connected with applied research

Establish both long and short term scientific and industrial research programs

b. Coordinate Scientific Activity

Direct activities of government and private sectors toward integrated, coordinated, and intensified R & D programs

Aid and coordinate the activities of academic institutes in their scientific pursuits

Enable the country to develop R & D more systematically

Direct R & D teams to specific tasks of major economic importance

c. Promote Scientific Activity

Promote scientific education regionally

Promote and encourage research of both the Government and private sectors

Promote science consciousness

Promote social science research

Encourage the domestic and foreign sectors to furnish technical and financial assistance for R & D

Promote R & D projects considered necessary for the advancement of science

Foster, promote, sustain by all appropriate means, the cultivation of basic and applied R & D

Encourage R & D by creating an atmosphere favorable to it

8. Facility Development
   a. Improve Scientific Facilities
      Improve scientific research facilities in research institutes and universities especially in those which have a fairly good foundation
      Strengthen the educational system to provide a competent source of trained manpower
      Expand well equipped laboratories with aid from government, industry, and international assistance

   b. Provide New Scientific Facilities
      Create new laboratories according to the needs of the state
      Establish, maintain, and manage research facilities to further scientific and industrial research
      Establish facilities for instrument repair and calibration
      Provide a central service for making scientific tests and measurements
      Establish standards, quality control and documentation facilities

9. Education and Training
   a. Provide and Improve Scientific Careers
      Upgrade the careers of scientific investigators
      Furnish incentives for private and individual initiative in scientific work
      Recognize the work of scientists as an important component in the strength of the nation
      Insure that creative talent is encouraged
      Direct attention to welfare of scientific-academic community and professional requirements of members
      Encourage the discovery of new knowledge in an atmosphere of academic freedom
      Respect academic freedom but constrain scientists to keep in mind needs of country
      Create more opportunities and specific career positions for as many scientists as possible

   b. Provide Scientific Training
      Determine manpower requirements
      Arrange training courses, seminars, refresher courses, lectures, and technical conference for researchers
      Make provision to attract and keep advanced teaching and research scientists
      Develop a long-range technical manpower training program
      Develop programs for effective training and utilization of scientific manpower
      Insure an adequate supply within the country of high quality researchers
      Train researchers and later on, simultaneously, teachers and researchers
      Train technicians to fulfill the needs of industry
      Develop technical manpower

This classification of objectives provides the evaluation criteria by which the actual results of R & D performance can be measured against expected results. The process is somewhat similar to that of evaluating a company's R & D performance. There are limitations in making such a comparison; most obviously a country is not a company and the process of goal formation and goal attainment are not the same. Nevertheless, it is felt that the general process is sufficiently similar to use this approach, at least initially. In Setting Criteria for R & D[1], A. H. Rubenstein outlines the following operations in the process of evaluation:

1. Establishing criteria for the expected economic results--in terms of company income, growth, introduction of new products, and so forth. These criteria derive from the objectives of the company in supporting an R & D activity.

2. Observing (measuring, where possible) the actual economic results achieved. The time periods involved here are, of course, longer than those involved in the control process.

3. Comparing the actual economic results with the expected results.

4. Taking action to change design features or objectives where necessary.

The goal of this procedure in the case of a developing country, is a set of testable propositions that will relate the evaluating criteria to various aspects of the R & D pattern. This will be illustrated in Chapter IV, after selected research strategies and patterns have been considered.

III.3 Alternative Strategies

III.31 Framework of Analysis

To achieve the objectives classified in the preceding section, a number of strategies are emerging in the developing countries. A strategy is a specific means used for creating or maintaining an R & D estalbishment or group of establishments in developing countries. Typically, a strategy is proposed or put into operation by a specific sponsor or sponsor-client and results in the creation or support of a specific R & D institute.

Thus, at this point in the long range study, primary emphasis is on the analysis of organizations doing actual R & D work. It will also be important at a later point to examine the other components of the institutional network for scientific activity such as documentation centers and universities. These can be considered as supporting or auxilary strategies and are important in completely describing the R & D network of a given country.

The framework of analysis noted below has been found useful in describing the strategies for organizing R & D activity. It consists of dimensions or characteristics of the organization, which are considered most relevant to a study of this type and, in general, follow the analysis of the general model outlined previously. The dimensions are as follows:

1. Establishment of the Organization
   - Date Established
   - Location
   - Organizing Agent
2. Objectives
3. Sponsors
4. Clients (Users)
5. International Connections

6. Intranational Connections
7. Funding Methods
8. Facilities
9. Staffing
10. Portfolio
11. Training and Teaching Capability
12. Implementation of Results

Sponsors are those groups, organizations, or agencies which only provide the means for a particular R & D establishment to operate. They do not necessarily receive direct benefits or services from the R & D establishments they support. Such "pure" sponsors may include government agencies, international philanthropic organizations, or other granting agencies.

Clients are those organizations, agencies,or sectors of the economy that receive the benefit of R & D work. The "pure" client does not support a particular R & D establishment directly.

A further distinction, sponsor-clients, results from these two definitions by implication. These are organizations, or agencies that both provide direct support to a particular R & D establishment and receive direct benefit from it.

International and intranational connections are those contacts and relationships existing between organizations which are important to the advancement of the R & D work of the institute. This includes both formal continuing relationships and periodic or ad hoc arrangements such as conferences, seminars, and exchanges of personnel.

Funding methods includes the primary sources by which an organization is supported and the agencies which make occasional grants, but do not provide continuing support.

Facilities covers both the physical plant and equipment for doing R & D work and the supporting activities such as libraries, information services, and testing laboratories.

Staffing refers to the technical personnel and is considered as consisting of three levels; senior scientists with graduate training who direct projects or departments; junior scientists with the equivalent of a four-year college or university education; and supporting technical staff with a high-school education or its equivalent.

Portfolio refers to the actual list of projects on which a given institute is working. Where this information is not available, the major areas of concentration or departments are listed. Also, some attempt has been made to distinguish by questionnaires and correspondence the balance between basic and applied research.

Training and Teaching capability includes those activites designed to educate students or staff members on a more or less formal basis through programs ranging from regular classes to counterpart training and apprentice programs.

Implementation of results refers to those organized techniques by which an institute attempts to insure the utilization of R & D results.

These characteristics can be considered as primary characteristics which in turn, can be subdivided into secondary characteristics. For instance, the primary characteristic "international connections" would include the following secondary or sub-characteristics: 1) International Agency such as the United Nations; 2) Regional Agency such as the Columbe Plan; 3) Bi-lateral such as AID; 4) Bi-lateral-Contract such as the U.S. Air Force; 5) Foreign University; 6) Foreign research institute; 7) International Corporation; and 8) an International Corporation's own research facility.

The original intention of this framework of analysis was to provide a basis for a comparative analysis of strategies. This was attempted, but with limited success, in a previous paper Strategies and Patterns for the Organization of Applied Research in Latin America and Southeast Asia, by A. H. Rubenstein and E. C. Young. The primary difficulty was the scarcity of data, and although much more information is now available, it is still a major limitation on a study of this type. The approach used in this thesis is to isolate strategies and strategy elements that will provide a basis for analyzing R & D patterns in the developing countries, rather than emphasizing a comparative analysis of strategies themselves, although the data presented here will be useful in that long run goal.

As noted, it is not always possible, due to the incompleteness of some of the information received to consider each dimension of each strategy. However, a selection of strategies has been made and described as completely as possible along these lines. This selection was made using primarily two criteria: (1) the strategy was commonly used in a number of countries, (2) the strategy, although less representative of a general type, was of interest due to unique and perhaps important organizational features. An effort has been made to present as concise a picture as possible of each strategy; the essential idea is to convey an idea of the major organizing principles and distinguishing features of the institute, but they are not ordered according to any criterion of importance.

III.32 Illustrative Set of Strategies

III.321 International Strategies

III.3211 Strategy - International agency program for developing applied R & D institutes

Illustrative Case - United Nations Special Fund

Dimensions of the Strategy

Establishment
Year - 1959
Location - United Nations Headquarters, New York
Organizing Agent - United Nations General Assembly

Objectives - The overall aim is to raise production and productivity by doing necessary pro-investment work of three main types:

(1) Surveys and Feasibility Studies to reveal wealth-producing potentialities
(2) Applied research to find new uses for local materials and products
(3) Manpower Training and Technical Education

Sponsors - Members of the General Assembly who wish to make voluntary pledges; in 1963 this consisted of 102 members.

Clients (Users) - Governments of low-income countries which are members of the United Nations.

International Connections - These consist of all governments of member nations and all international organizations affiliated with the United Nations. More particularly the executing agencies responsible for administering the projects include: United Nations (UN); International Labor Organization (ILO); Food and Agricultural Organization (FAO); United Nations Educational, Scientific and Cultural Organization (UNESCO); World Health Organization (WHO); International Bank for Reconstruction and Development (IBRD); International Civil Aviation Organization (ICAO); International Telecommunication Union (ITU); World Meterological Organization (WMO); and International Atomic Energy Agency (IAEA).

Intranational Connections - Cooperating agencies on specific projects, primarily the national government and its appropriate department or ministry.

Funding Methods - Voluntary pledges of 102 participating Governments (in 1963). From 1959 through 1963, the Special Fund provided $250,000,000 for 286 projects and member governments an average of $1,200,000 in additional funds for each project. One of the goals is to make the projects self sustaining as soon as possible by gradually decreasing Special Fund support. Approximately one-fifth of the funds go for research projects, fifty-seven such projects with a total cost of $131,335,713 had been approved by the end of 1963.

Facilities - These are developed as necessary on each project. One of the goals is to create a permanent unit which, in the case of research and training projects usually means establishing physical facilities.

Staffing - By 1963, 850 experts from 55 countries have worked on projects in 81 countries and territories. Local personnel are upgraded as soon as possible.

Portfolio - The applied research institutes established by the Special Fund work in a variety of fields depending on the needs of the country in which it is located, but generally they are designed to improve manufacturing techniques, design new equipment and products, promote better use of local materials and carry out studies and field work to raise productivity.

Training and Teaching - Over 40 per cent of Special Fund's resources is devoted to projects having education and training as their main objective. On research projects training is mainly by informal programs and counterparts.

Implementation of Results - To insure maximum participation by member Governments, they must contribute on the average 60 per cent of the cost of the project in money, buildings land, and equipment. In special cases where a project is deemed especially important the Special Fund may contribute more. In all cases support is to be eventually withdrawn in order to insure a viable unit supported at the national, or at most, regional level.

Distinguishing Features of the Strategy*

1)"Full partnership between industralized and the developing countries in mobilizing money, men and equipment.

2) "Coordinated use of the experience and facilities of organizations in the United Nations as executing agencies for projects.

3) "A high degree of selectivity in projects to ensure they are part of a consistent national economic policy, will contribute substantially to the countries economic growth, and are harmonized with both multilateral and bilateral assistance.

*Note: These features are considered the essential working principles by the Special Fund.

4) "A heavy contribution by the recipient Government for the implementation of projects which is intended to (a) demonstrate the readiness of a country to help itself to a maximum; (b) establish its priority of interest in the project; and (c) spread among more projects the "seed" effects of the skills and equipment provided by international funds."

Source of Information:
Target: An Expanding World Economy, A United Nations Special Fund Report (New York: United Nations, 1963)

III.32.2 Strategy - Foundation Sponsored, international cooperative program in basic and applied agricultural research.

Illustrative Case - The International Rice Research Institute

Dimensions of the Strategy

Establishment
Year - 1960
Location - Los Banos, Lagana (40 miles south of Manila)
Organizing Agents - Rockefeller Foundation with cooperation from the government of the Philippines

Objectives
(1) Conduct basic research on the rice plant, on all phases of rice production, management, distribution, and utilization with a view of attaining nutritive and economic advantage for the people of Asia.
(2) Publish and disseminate research findings and recommendations of the institute.
(3) Distribute improved plant materials to regional and international research centers.
(4) Develop and educate promising young scientists, primarily from South and Southeast Asia through a resident training program.
(5) Establish, maintain, and operate an information center and library.
(6) Organize and hold periodic conferences, forums, seminars, whether international, regional, or local.

Sponsors - Rockefeller and Ford Foundations

Clients (Users) - Rice growing nations, primarily those in South and Southeast Asia.

International Connections - Universities of South and Southeast Asia and the Far East.

Intranational Connections - College of Agriculture of the University of the Philippines.

Funding Methods - The annual appropriation by the Rockefeller Foundation is $405,000. The Ford Foundation supplied an initial grant of $7,150,000 for building, equipment, and experimental fields; in addition, Ford made a grant of $750,000 to cover a three year period for training scientists. Collaborating governments and international agencies are urged to cover training costs.

Facilities - Research facilities include a laboratory for research in plant breeding, genetics, taxonomy, biochemistry, agronomy, soil chemistry, soil microbiology, plant physiology, plant pathology, entomology, agricultural economies, and statistics. Additional facilities include greenhouses, experimental fields, service building, administrative center, library, and housing.

Staffing - In 1962, the staff, whose members were from six nations, included 12 doctoral level scientists and four masters degree level scientists.

Portfolio - Programs are carried out in varietal improvement, plant physiology, soil chemistry, agronomy, plant pathology, chemistry, agricultural economics, soil microbiology, and agricultural engineering.

Training and Teaching Capability - Besides training promising students, graduate study is pursued at the nearby college of Agriculture of the University of the Philippines, and a limited number of selected scientists and faculty members are offered specialized training.

Implementation of Results - This is provided for in the original grant by the Ford Foundation which stipulates strengthening national agencies which disseminate results; also, provision is made for periodic visits to participating countries by the staff.

Distinguishing Features of the Strategy

1) Exclusive focus on one subsistence crop of basic economic importance in several nations.
2) Cooperative financing by two major foundations.
3) Continuing support and stable source of funds provided by a foundation.
4) Emphasis on basic research in several disciplines and in all phases of the production and distribution cycle.
5) An international staff with emphasis on the doctoral level.
6) A selective training program concentrating on a relatively small number of students from several participating countries.
7) An international program but with regional emphasis in one area.

Source of Information

The International Rice Research Institute: Annual Report 1961-1962

III.3213 Strategy - Branch Laboratory of an international commercial corporation

Illustrative Case - CIBA, Limited

Dimensions of the Strategy

Establishment

Year - 1961
Location - Bombay, India
Organizing Agent - CIBA, Limited

Objectives - To establish and operate all-Indian staffed research center doing (1) fundamental chemical and biological research in pharamaceuticals and (2) developmental work in dyestuffs. The diseases of India and South Asia will receive special attention.

Sponsors - CIBA, Limited

Clients (Users) - CIBA Limited, especially CIBA of India; private firms which enter into joint ventures such as Atul Products, Ltd. on dyestuffs.

International Connections - CIBA research centers in Switzerland, Great Britain, and the U.S.

Intranational Connections - The Central Drug Research Institute at Lucknow; Atul Products, Ltd.

Funding Methods - Company funds and joint ventures in private industry.

Facilities - The complex located on 70 acres includes 29 buildings, three of which contain 80 laboratories, an animal house, a scientific library, administrative offices, and staff living quarters.

Staffing - In 1963, CIBA reported that the staff included 170 employees with 24 top Indian scientists. Emphasis is placed on the objective of an all-Indian staff including the direction of the institute.

Portfolio - The two main areas of research are pharmaceuticals and dyestuffs. Pharmacology laboratories are equipped for studies in endrocrinology and taxicology; and microbiology laboratories for studies in a parasitology and bacteriology. A third group of laboratories synthesizes drugs from natural plant and animal products. Development work is done in dyestuffs.

Training and Teaching Capability - As a commercial laboratory, teaching is not a major aspect of the institutes program.

Implementation of Results - Results are used directly in CIBA Limited or with partners in joint ventures.

Distinguishing Features of the Strategy

1) A private research laboratory directly oriented to fundamental problems in a developing region.
2) The first center for basic chemical and biological research to be built by private industry in South Asia.

Source of Information:

"CIBA-normama - Featuring the Inauguration of the Goregaon Research Centre," CIBA Journal, no. 25, Spring, 1963.

III.3214 Strategy - Private international association sponsored research program for a commercial crop

Illustrative Case - Empire Cotton Growing Corporation

Dimensions of the Strategy

Establishment

Year - 1921

Location - Headquarters in London with field work in Uganda, Kenya, Tanganyika, Nyasaland, Northern Nigeria, the Republic of the Sudan, Aden and the West Indies.

Organizing Agent - The United Kingdom

Objective - To extend and promote the growing of cotton.

Sponsors - The United Kingdom and the eight countries listed above.

Clients (Users) - Same as "Sponsors."

International Connections - Commonwealth research organizations, the United Kingdom Colonial Office, FAO, Shirley Institute in Manchester.

Intranational Connections - Departments of Agriculture of participating countries.

Funding Methods - An initial capital grant by the British government in 1921 provides 70,000 (pounds) annually. Also, from 1921 to the late 1940's the cotton industry in the United Kingdom made annual payments. Currently, overseas Governments pay 125,000 (pounds) annually.

Facilities - A central research station at Namulenge in Uganda has 2,000 acres, a dozen research officers, 70 local technical assistants and hundreds of farm laborers. In other areas the Corporation works through Government stations which provide housing, laboratory accomodations, equipment and junior staff.

Staffing - The overseas staff is presently recruited mainly from the United Kingdom with junior staff and labor provided locally. This overseas staff is disbersed as follows: West Indies - 11; Nigeria - 7; Sudan - 17; Uganda - 3; Kenya - 3; Tanganyika - 9; Nyasaland - 6; Aden - 10.

Portfolio - Basic and applied research in all areas of cotton growing including development of new strains, development of genetic pool of information of characteristics on 14,000 types of cotton, studies in etomology, pathology, physiology, and agronomy.

Training and Teaching Capability - Some extension work with Departments of Agriculture of participating countries, but main emphasis is on research and experimentation.

Implementation of Results - Close cooperation is maintained with national research organizations in the United Kingdom and East Africa.

Distinguishing Features of the Strategy

(1) The corporation is independent and interterritorial which may contribute to freedom and flexibility of operation and closer cooperation between countries.
(2) Concentration on one crop in a variety of climatic and geographic regions contributing to systematic comparative studies.

Source of Information:

Empire Cotton Growing Corporation (London: Empire Cotton Growing Corporation, June, 1961).

III.3215 Strategy - Provision of scientific help by individual scientists from a scientifically advanced country.

Illustrative Case - VITA (Volunteers for International Technical Assistance, Inc.)

Dimensions of Strategy

Establishment

Year - 1960
Location - Schenectady, New York
Organizing Agents - volunteer American scientists and engineers in industrial, state, and university laboratories in the Albany-Schenectady-Troy area of the state of New York.

Objective - To assist people who are seeking help in raising the standards of living in other nations.

Sponsors - same as "Organizing Agents."

Clients (Users) - Primarily organizations working in development areas such as missionary groups and agencies of smaller nations.

International Connections - No formal connections.

Intranational Connections - Since this is a volunteer group, there are no fixed organizational affiliations, except those which members have individually. These can be considerable in number but limited in effort due to the voluntary nature of the work.

Funding Methods - Volunteer work of associates and contributions.

Facilities - No organized facilities except those owned by associates.

Staffing - Volunteers include physicists, chemists, biochemists, biologists, geologists, mathematicians, metallurgists, physicians, and electrical, nuclear, mechanical, chemical, civil and metallurgical engineers.

Portfolio - VITA welcomes all technological problems arising from the modernization efforts of the world's nations. Criteria for accepting problems is based solely on the ability and competence to VITA's voluntary participatns to contribute to the practical solution of such problems. These include such problems as (1) requests for development work such as a solar cooker, (2) requests for survey reports on the state of the arts such as family size units for the disalination of water; and (3) requests for specific well-defined technological problems as water lifting devices for irrigation.

Training and Teaching Capability - not relevant

Implementation of Results - not relevant, only requests are handled and it is presumed the initiating agency will be responsible for implementation.

Distinguishing Features of Strategy

(1) The voluntary, non-profit rendering of technical assistance by already fully employed scientists and engineers.
(2) The wide range of skills registered to assist on requests which maximizes the possibilities of handling requests which are received.

Source of Information:

Albert H. Rubenstein and Earl Young, "An Analysis of Alternative Strategies for Organizing the Applied Research Activities of Developing Countries," (Department of Industrial Engineering, Northwestern University, 1963) pp. 19-20, 26-27.

III.322 Regional Strategies

III.3221 Strategy - Regional applied research laboratory established by an international governmental agency

Illustrative Case - El Institute Centreamericano de Investigacion y Technologia Industrial (ICAITI)

Dimensions of the Strategy

Establishment

Year - 1955
Location - Guatemala City, Guatemala
Organizing Agents - Costa Rica, Guatemala, Honduras, Nicaragua, and El Salvador in cooperation with the United Nations Technical Assistance Administration (UNTAA)

Objectives

(1) To serve as professional consultant to private initiative in all phases of the study and implementation of industrial projects.
(2) To give practical advice to manufacturers in solving production problems and difficulties.
(3) To undertake technical investigations on the utilization of raw materials; the development of manufacturing techniques and processes; the elaboration of new products.
(4) To promote the application of adaptation of technological knowledge and modern methods of productivity in Central American industry.
(5) To advise those public and private institutions concerned with industrial development.

Sponsors - same as "Organizing Agents" above.

Clients (Users) - The governments and private industry of Central America are the primary clients.

International Connections - UNTAA and the UN Special Fund, Office of the Technical Services of the United States Department of Commerce, OECD.

Intranational Connections - Universities in Central America.

Funding Methods - Funds come primarily from three sources: the UN Special fund, member nations, and private clientele. UN contributions in 1956 through 1958 ran $84,000, $98,000 and $91,000, they were decreased to $52,000 in 1964 and were expected to terminate that year. Contributions by member nations increased progressively from $32,000 in 1956, $40,000 in 1957, $47,000 in 1958, to $52,000 in 1964. Earnings from private clientele have steadily increased from $1,800 in 1956, $21,730 in 1957, $33,168 to over $200,000 in 1963.

Facilities - Buildings include laboratories, pilot plant, workshop, library and administration.

Staffing - In December 1958, there were 51 employees including non-professional personnel and manual workers. Of these, eight staff members, including the director were provided and renumerated by UNTAA. In the early stages two experts were provided by the International Labor Organization and one by UNESCO. The staff includes mechanical engineers, chemical engineers, chemists, electrical engineers, geologists, industrial economists, experts in accounting, adminstration, productivity, rationalization and normalization.

Portfolio - Projects are both national and regional in scope and emphasis is on applied R & D. National projects include conservation of foodstuffs under tropical conditions; utilization of meat by-products; utilization of molasses; and processing of resin, turpentine, essential oils and medicinal plants. Regional projects include recovery of sulpher from volcanic mud; utilization of heniquen waste; and developing building materials.

Teaching and Training Capability - A program is contemplated which will provide training for students in cooperation with the universities of Central America. There is no formal training program as such for industry except as provided for on an instructional basis through the consultation and advisory services.

Implementation - Most projects are client-initiated and this provides a strong motivation for cooperation in installation. Also, there is a full range of services which includes development work which overlaps into production phases. Hence sponsored projects are not as readily implemented.

Distinguishing Features of the Strategy

(1) A regional cooperative organization with multi-government sponsorship.
(2) Several substantial sources of funds in initial phases of organization.
(3) Emphasis on research for private industry.

Source of Information:

Instituto Centro Americano de Investigacion Y Technologia Industrial, Central American Research Institute for Industry (Guatemala)

III.3222 Strategy - Military-Political sponsored regional institute connected with educational institution

Illustrative Case - SEATO Graduate School of Engineering

Dimensions of the Strategy

Establishment

Year - 1959
Location - Bangkok, Thailand
Organizing Agents - The SEATO Council

Objectives

(1) To train graduate engineers in research
(2) To carry out special research programs for practicing engineers
(3) To carry out research programs by students, faculty and research staff.

Sponsors - Member countries of the SEATO Treaty including Borneo, Burma, Cambodia, Ceylon, India, Indonesia, Laos, Malaya, Pakistan, Philippines, Sarawak, Singapore, South Vietnam, Thailand.

Clients (Users)- Although primarily a graduate school for engineering training, an important activity is sponsored research for such companies as the Pure Oil Company; Bureau of Ships, U. S. Department of Navy; Bangkok Sanitarium.

International Connections - These include member countries of the SEATO Treaty; Colorado State University through the U. S. Government since Colorado State has provided the majority of the faculty; the United Kingdom which has provided considerable technical assistance.

Intranational Connections - Chulalongkova University in Bangkok

Funding Methods - The school is supported in some way by all member countries; Thailand through Chulalongkova University has contributed land, buildings, professors, service staff members, operating funds and equipment; the United States, through Colorado State University, supplied the teaching staff, also funds and equipment; the United Kingdom contributed most of the equipment, a faculty member, service staff and operating funds; other countries have contributed faculty members, funds for scholarships, books, and equipment.

Facilities - These include offices, classrooms, hydraulics laboratory, structures laboratory, highway and materials laboratory, library and workshops.

Staffing - Nine of the staff members are from outside the area, seven from the United States, one from Britain, one from France. Within the area, five are from Thailand and one from New Zealand. Of these nine are at the doctoral level and six at the masters level.

Portfolio - Projects are conducted in the three major areas of Highway Engineering, Hydraulic Engineering, and Structural Engineering.

Training and Teaching Capability - the main function of the school is teaching graduate students. In addition, special programs are designed for practicing engineers.

Implementation of Results - Other than sponsored research, the investigation done by the school are primarily educational in nature; implementing results is not a main concern of the school.

Distinguishing Features of the Strategy -
(1) Multi-national military-political sponsorship
(2) A variety of funding methods with contributions reflecting interest and ability to participate

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Source of Information:

SEATO Graduate School of Engineering: Catalog for 1962-1963.

SEATO Graduate School of Engineering: Research Summary No. 2, October, 1962.

III.3223 Strategy - Regional research laboratory established by a private foundation.

Illustrative Case - The Institute of Nutrition of Central America and Panama.

Dimensions of the Strategy

Establishment

Year - 1949
Location - Guatemala City, Guatemala
Organizing Agents - Representatives of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, the Pan American Sanitary Bureau of the Pan American Health Organization, World Health Organization and representatives of the W. K. Kellog Foundation.

Objectives - To investigate the nutritional conditions of Central America; to search for solutions to the problems revealed; and to help member countries apply the solutions once they have been found.

Sponsors - same as "Organizing Agents" above.

Clients (Users) - Member nations primarily through the Ministers of Health, Department of Nutrition.

International Connections - World Health Organization, Food and Agricultural Organization, Inter-American Institute of Agricultural Science in Turrialba, Costa Rica.

Intranational Connections - Universities in each of the member nations, national agricultural research stations, and Roosevelt Hospital in Guatemala adjacent to the Institute.

Funding Methods - Member countries contribute $17,500 each on an annual basis. The balance of the annual budget, $100,000 in 1961, was financed through assistance from the Pan American Sanitary Bureau and contributions from foundations and other sources.

Facilities - The main adminstrative building and laboratories are located in Guatemala City with new facilities being added currently. There is a 180 acre farm for studying animal nutrition and nutritive value of plant varieties. The library is one of the most complete in Latin America on nutrition. Nearby facilities include Roosevelt Hospital and the facilities of medicine and agriculture at the University of San Carlos, Guatemala.

Staffing - The breakdown of the scientific staff by educational level in 1961 is as follows: 19-Ph.D.; 8-M.S.; 12-B.S. The total staff at the Institute include 139 in 1961. Forty-six of these are professional and are engaged in research, field and training programs, and administration of the Institute. From the beginning an effort was made to achieve a level of competence equivalent to that of a comparable institute in the U.S. or Europe. The first director was from the United States and served from 1949-61. The newly appointed director is a Guatemalan.

Portfolio - The current research program is divided into five general areas of study: evaluation of nutritional status; protein malnutrition in children and its prevention; maximum utilization of available foods in specific areas; interrelation of nutrition and infection; and the relation of diet to degenerative disease.

Training and Teaching Capability - As needs have been recognized where training was most needed, programs were expanded and formalized. Approaches include fellowships for training in research; short-term training of a specialized type; courses in the techniques of dieting surveys; a summer course in public health nutrition for physicians; a two-year course for nutritionists and dietitians; a specialized course in public health nutrition for Latin American dietitians; and, finally, conferences and seminars on specialized subjects for various groups of workers in the field of nutrition.

Implementation of Results - The extensive training program is the main direct means of implementing the results of research at the Institute; cooperation with governmental departments of nutrition in another means. A more recent method consists of licensing private firms to produce and market products such as Incaprina, a low cost protein supplement.

Distinguishing Features of the Strategy

(1) A regional cooperative effort.
(2) A close integration of teaching, research, and extension.
(3) A relatively complex matrix of clients and sponsors.
(4) Close cooperation by all members and equality in the distribution of effort is implied by equal contributions by member nations.
(5) Extensive training programs are a primary means of implementation.

Source of Information:

The Institute of Nutrition of Central America and Panama (Guatemala: 1962).

Institute of Nutrition of Central America and Panama, Incaprina (Guatemala, C.A., 1962).

III.323 National Strategies

III.3231 Strategy - National Government sponsored and administered autonomous, multi-institute program.

Illustrative Case - The Council of Scientific and Industrial Research of Pakistan (CSIR)

Dimensions of the Strategy

Establishment

Year - 1960
Location - Karachi, Pakistan
Organizing Agent - A scientific commission reporting to the Minister of Industries established a Pakistan Science Foundation to coordinate scientific research in Pakistan. The CSIR is a unit of the Foundation.

Objectives

(1) The initiation, promotion and guidance of scientific and industrial research bearing on problems connected with the establishment and

development of industries or with other matter referred to the council by the Central Government.

(2) To establish or develop national institutions for research, to utilize the economic resources of the country in the best possible manner.

(3) To make grants in aid for specific research schemes at universities and other research institutions in Pakistan.

(4) To undertake and foster developmental research for the utilization of discoveries and inventions resulting from researches of the council.

(5) The establishment and award of research fellowships.

(6) The collection and dissemination of information of scientific and industrial matters, and the publication of scientific reports and periodicals relating to the activities of the council.

(7) To encourage the establishment of industrial research associations by various industries.

(8) To maintain contacts with industrial research organizations in other countries.

Sponsors - The government of Pakistan. A liaison is maintained with the CSIR by the government through a Department of Scientific and Industrial Research, attached to the Ministr of Industries. (See also "Organizing Agents" above.)

Clients (Users) - The Government of Pakistan, the industrial sector, the universities.

International Connections - The British Commonwealth scientific organizations, and UNESCO.

Intranational Organizations - Institutes are located near universities to allow maximum participation, universities are represented on the governing board of CSIR.

Funding Methods - Government Budget

Facilities - Permanent facilities are maintained at a central laboratory in Karachi and regional laboratories at Dacca, Lahore, and Peshawar. (See "Portfolio" for individual types of laboratories based on R & D programs.)

Staffing - Primarily nationals who are on a permanent basis. In addition, temporary scientific and other staff are appointed under the council for handling various research schemes at the universities and other research institutions.

Portfolio - by laboratories, these include:

Central Laboratory at Karachi
1) Physical Research and Testing
2) Chemical Research
3) Biochemical Research
4) Drugs and Pharmaceuticals Research
5) Building Materials Research
6) Fuel Research
7) Plastics Research

Regional Laboratory at Daeca
1) Leather Research
2) Fuel Research
3) Food and Fruit Research

4) Plant and Animal Products Research
5) Glass and Ceramics Research

Regional Laboratory at Lahone
1) Metallurgical Research
2) Industrial Fermentation Research
3) Oils and Fats Research
4) Glass and Ceramics Research
5) Food and Technology Research

Regional Laboratory at Peshawar
1) Indigenous Drug research
2) Wood Research
3) Fruit Technology Research
4) Mineralogical Research

Training and Teaching Capability - By locating near universities it is possible to cooperate with faculty members and students in organizing, directing and financing specific projects in each of the laboratories.

Implementation of Results - Liaison with industry is maintained through an industrial liaison service. Also, a National Scientific and Technical Documentation Center and a Journal of Scientific and Industrial Research have been established.

Distinguishing Features of the Strategy
1) Capability to establish research institutes in response to particular needs of the economy.
2) Location of research centers next to universities to increase possibility of maximum cooperation.
3) Geographic dispersion of institutes to various parts of the country.
4) Attempt to coordinate and integrate government, university, and industrial research in a given field.
5) Emphasis on close relationships of R & D efforts to national economic development.

Source of Information:

The Promotion of the Sciences in the Commonwealth, prepared by the Reference Division, Central Office of Information; London, September, 1960.

III.3232 Strategy - National Government sponsored central applied research institute for industry.

Illustrative Case - Ceylon Institute of Scientific and Industrial Research (CISIR)

Dimensions of Strategy

Establishment

Year - 1955

Location - Columbo, Ceylon

Organizing Agents - The government of Ceylon by Acts of Parliament, on the basis of studies and recommendations of the Ministry of Industries, Housing, and Social Services, the Ministry of Finance, the IBRD and UNTAA, established the institute in cooperation with the UNTAA.

Objective - The major objective is to further Ceylon's productive development through applied research and technology.

Sponsors - The Government of Ceylon and the United Nations Technical Assistance Administration

Clients (Users) - In the first two years of operation (1955-7) the CISIR rendered paid technical services to private firms and public agencies including seven Departments of Ministries of Government, the Gal Oya Development Board, six Government owned factories, the Development Finance Corporation, the Bank of Ceylon, the Tea Research Institute, the Coconut Research Institute, two producers associations, individual exporters, and 72 private manufacturing and business firms.

International Connections - Major connections include the United Nations Technical Assistance Board and the Special Fund, information services and research councils in India, Pakistan, Australia, Canada and the United States.

Intranational Connections - These include the Institute on the Committee on Standards, Low Cost Housing, the Planning Council, Government Ministries, the Tea Research Institute, the Coconut Research Institute, the Rubber Research Institute, and the Technical Training Institute.

Funding Methods - The CISIR received $210,000 annually from the government for the first five years; other income is derived from CISIR's private clientele. Income from the private sector increased as follows during the first five years (1955-1959) $53,127; $118,770, $91,326; $167,173; $225,000. At the end of the third year there were 145 paying clients, of these, 115 were private firms. Assistance in the form of equipment donations have been made by the Columbo Plan, the Government of Ceylon, U. S. Agency for International Development and the Asia Foundation. Funds were provided fourthly by the International Bank for Reconstruction and Development and the UNTAA for a director and a chief engineer for five years. The International Cooperation Administration of the U. S. provided consultants, scholarships, equipment and books.

Facilities - New, enlarged headquarters were established with laboratories, a pilot plant, a workshop, and library. The equipment was purchased with the objective of being flexible enough to handle unforseen local problems, ie, the chemical engineering equipment is planned on a unit-process basis.

Staffing - At the end of five years, excluding consultants, the institute had a Director, a chief research officer, a chief administrative officer, tea research officers, eight research assistants, an accountant, four Management Counterparts, skilled workmen and administrative staffing, in all, 76 persons. The staff doubled in five years, but not in the R & D section; in 1960, four members of the staff were at the Ph.D. level. Staffing included many foreign experts.

Portfolio - The R & D Division had programs in General Analytic Chemistry, Chemical Technology, Organic Chemistry of Natural Products, and Applied Physics and Electronics.

Training and Teaching Capability - The staff itself has received training abroad through scholarships and fellowships. In addition, some members of the staff received training through counterpart training at the institute with foreign experts. There is an apprentice training program in the Institute Workshops.

Implementation of Results - Due to the scarcity of know-how in Ceylon it is necessary for the CISIR to provide a Management Consultation Service to insure implementation. This includes exploring markets, designing buildings, laying out machinery and introducing costing procedures. Some projects are insured implementation since they are client initiated.

Distinguishing Features of the Strategy

1) A wide range of clients in both the public and private sectors.
2) Problems and projects are initiated by both the institute and clients.
3) There are many clients and many sponsors, but they do not overlap except for the Government of Ceylon and then not within the same ministry.
4) Extensive reliance on cooperation within the Commonwealth and secondarily with the United States.
5) Extensive intergovernmental and industry connections with little emphasis on academic connections.
6) Heavy reliance on client fees as a source of funds.
7) Varied, but limited, sources of international funding.
8) Adaptable facilities to accomodate client initiated problems and projects.
9) Reliance on foreign experts, counterpart training and gradual replacement with nationals.
10) Implementation through a consulting service.

Source of Information:

Fifth Annual Report of the Director to the Governing Board of the Ceylon Institute of Scientific and Industrial Research, May, 1959 to April, 1960, by the Ceylon Institute of Scientific and Industrial Research.

Technology for Industrial Progress No. 4, 1959; prepared by Ceylon Institute of Scientific and Industrial Research.

The C.I.S.I.R. a report to the nation (No. 1, Columbo, Ceylon: Ceylon Institute of Scientific and Industrial Research; May, 1965).

III.3233 Strategy - National government departmental research group

Illustrative Case - The Army Research and Testing Laboratory of the Republic of Korea.

Dimensions of the Strategy

Establishment

Year - 1948
Location - Seoul, Korea
Organizing Agent - Government of Republic of Korea

Objectives

1) To plan, prepare, and conduct the Military R & D Program.
2) To plan and prepare Military Specifications and Standards on Military Procurement Items.
3) To conduct physical and chemical analyses and tests on materials procured by ROK Armed Forces.
4) To provide all elements of ROK Forces with Scientific and Technical services.
5) To manufacture and produce food items, metallic supplies and others at pilot plant scale.

Sponsor - The Government of the Republic of Korea through the Ministry of National Defense.

Clients (Users) - The Armed Forces of the Republic of Korea

International Connections - On May 15, 1963, the Defense Department Exchange Program was established between the United States of America and the Republic of Korea to exchange information of mutual interest.

Intranational Connections - Scientific information is exchanged with the various universities in Korea and other government research institutes.

Funding Methods - Government funds determined in the annual budget.

Facilities - Laboratories to conduct R & D work in the fields noted under portfolio; in addition, the Food division maintains a pilot plant.

Staffing - The scientific staff numbers 100 employees; the technical staff includes 29.

Portfolio - R & D in the Food Division includes work in nutrition, microbiology, cookery, and packaging; the Chemistry Division includes organic chemistry, explosives, fuels, medicine, inorganic chemistry, and radio isotopes; and the Machine-metal Division emphasizes machine design and work on metallic materials. In addition, there is an Electricity-Physics Division, and a Textile and Leather Division. The distribution of effort can be approximated by the breakdown in the annual budget which is as follows:

Natural Sciences, including		50%
Basic Science	35%	
Technological Science	10%	
Medical science	1%	
Agricultural science	3%	
Nuclear science	1%	
Test and Analysis		25%
Analysis for Military Specification		25%

Teaching and Training Capability - Staff members may be sent on an individual basis to foreign universities. Special training courses may be given as the programs in Radiological Training for all Korean Army Officers in 1963.

Implementation of Results - There is no specialized section for this. Inasmuch as the laboratory is a part of the Ministry of National Defense compliance is apparently achieved by virtue of government authority as exercised by the Chief of Staff.

Distinguishing Features of the Strategy

1) This laboratory is typical of those government ministries which operate laboratories as a part of their own organization.
2) An international agreement between counterpart agencies (the U.S. and Korean Departments of Defense).

Source of Information:

"Directory of the Main National Scientific Research Organization in the Republic of Korea" (February, 1964).

III.3234 Strategy - Foundation sponsored, national cooperative program in basic and applied agricultural research.

Illustrative Case - The Mexican Agricultural Program of the Rockefeller Foundation

Dimensions of the Strategy

Establishment

Year - 1941
Location - Headquarters, 40 London Street - Mexico City, Mexico, D.F.
Organizing Agents -The Rockefeller Foundation in cooperation with the Mexican Government.

Objective - As stated in the agricultural Sciences program of the Rockefeller Foundation, the general objective is to direct primary attention to the increased production of basic food crops in selected regions of the world.

Sponsors -The Rockefeller Foundation in cooperation with the Ministry of Agriculture of the Mexican Government, the Ford Foundation, and the U. S. Agency for International Development.

Clients (Users) - The Mexican Government

International Connections - The International Food Corporation Improvement Program initiated by the foundation throughout the world for improving corn, wheat, and potato production, puts Mexico in touch with many nations with similar problems. The extensive training program provides a liaison with many U. S. universities. Cooperation is closer with FAO, the U.N. Food and Agricultural Organization.

Intranational Connections - These include collaborating members of the graduate faculty, National School of Agriculture at Chapingo; members of the National Seed Production Agency; and members of the National Institute of Agricultural Research.

Funding Methods - The foundation activities function as "seed corn" by initiating programs in which they pay the whole or major portion of expenses initially and gradually reduce funds and personnel as the institutions established are self-supporting. To indicate the magnitude of these activities, the Foundation spent $8,474,812 on the operating program of the Mexican Agricultural Program from 1941 through 1962.

Facilities - The Natural Institute of Agricultural Research has Central laboratories in Mexico City at the Rockefeller Headquarters. The National Institute for Animal Research has a central research center on the outskirts of Mexico City and a growing network of research stations which now include five stations. Nearby facilities include the National School of Agriculture in Chapingo and the University of Mexico.

Staffing - Initially, foundation scientists staffed the program using Mexican scientists where possible. An immediate goal was to begin training and upgrading staff until today only one section head in the National Institute for Agricultural Research is from the foundation. The National Institute for Animal Research, a much younger organization, is directed by a foundation scientists; also, two section heads are from the foundation. The distribution of the staff according to skill level is as follows:

The Rockefeller Foundation: 9-Ph.D.
The National Institute for Agricultural Research: 9-Ph.D. (in addition to four from the Foundation on loan); 15-M.S.; 25-B.S.
The National Institute for Animal Research: 3-Ph.D.; 6-M.S.; 27-B.S.

Portfolio - Programs in both basic and applied research, with emphasis on the latter. Work is being done in the following areas: corn, sorghum, wheat, oats, barley, potatoes, soil fertility and management, poultry, animal pathology, animal nutrition, and agricultural economics.

Training and Teaching Capability - The Program receives extensive aid from the Rockefeller Fellowship and Scholarship Program in the Agricultural Sciences. Of 291 active fellowships and scholarships representing 27 countries, 190 were from Latin America of which 65 were from Mexico. This was in the year ending June 30, 1963.

Implementation of Results - The close working relationship with the Ministry of Agriculture is the main assurance that results will be used. This is based on (1) an initial willingness to cooperate in establishing the institute; (2) the gradual increase of government funds in the project; (3) increased participation by nationals in the administration; (4) close liaison with the School of Agriculture and the extension service; (5) an agricultural information service in the Institute for Agricultural Research; (6) a library with technical services at Foundation headquarters.

Distinguishing Features of the Strategy

(1) Active participation and cooperation by the host government is a necessity.
(2) Close cooperation with local, national, and international agricultural organizations.
(3) The utilization of this national program in the international program, the International Food Crop Improvement Program. This assures continued contact with the foundation; extension of the benefits to other countries; additional training of the participating staff in conferences and symposia.
(4) Cooperative financing on a sliding scale with maximum foundation support initially which is gradually decreased until the project is self-supporting.

(5) Close supervision of the program by foundation personnel which is also withdrawn as soon as nationals take over.
(6) Emphasis on a few basic food crops and animals, but through a variety of basic and applied sciences.
(7) Emphasis on and financial support of a broad training program at the undergraduate and graduate level.
(8) Much attention to the institution-building aspects of the program.

Source of Information:

The Rockefeller Foundation, Program in the Agricultural Sciences: Annual Report 1962-63 (New York: Office of Publications).

III.3235 Strategy - Private national association sponsored research program for a commercial crop.

Illustrative Case - Asociacion Nacional del Cafe, Departamento de Asuntos Agricolas, Guatemala.

Dimensions of the Strategy

Establishment

Year - 1962
Location - Headquarters, Guatemala City, Guatemala with six regional stations in the coffee growing area.
Organizing Agents - The Asociacion Nacional del Cafe in cooperation with the Government of Guatemala

Objectives - To assist in all phases of coffee culture and to diversify agriculture in marginal coffee growing areas.

Sponsors - The Coffee Growers Association

Clients (Users) - The Coffee Growers Association

International Connections - FAO and the Special Fund of the United Nations, the University of Kentucky.

Funding - The coffee growers must pay a cost of $.25 per quartale (46 pounds) which covers association expenses. The research and extension service, in turn, operates on an annual budget submitted by the Director of Research and Extension and approved by the Board.

Staffing - The department is headed by a doctoral level scientist backed by a central staff of three including an entomologist. This group works with the extension service consisting of six field agents and a supervisor.

Portfolio - Research activities include chemical analysis of coffee samples; a study of leaf miner, growth and production of coffee treas; and diversification of crops in marginal coffee areas.

Teaching and Training Capability- The staff is trained abroad. A primary mission of the department is to provide information to help coffee growers through the extension service.

Implementation of Results - The results of research are implemented through a combination of publications, instruction pamphlets and the extension service.

Distinguishing Features of the Strategy
(1) The sponsors are the clients
(2) Funding is determined by an annual budget
(3) Source funds is a cost (or duty) on members.
(4) Research is oriented to immediate problems of growers.
(5) Research secondary to diffusion of technical knowledge.

As can be seen from the foregoing strategies, there is a great deal of variety within each dimension, indicative of innovative organization structures which have developed, especially since World War II, in response to the desire to initiate and conduct R & D in developing countries. Many more examples could have been included expanding the main points of each strategy. For instance the CSIR of Pakistan is representative of similar organizations in India, Ceylon, Ghana, Nigeria, and the other former British Colonies. The CISIR of Ceylon, a central industrial research laboratory is found under different types of sponsorship and with different connections and funding methods in Korea, Burma, Columbia, and Mexico, while the Central American Institute for Industrial Technology (ICAITI), resembles a similar regional institute in Africa, the East African Industrial Research Organization. Finally, SEATO sponsorship of graduate research in civil engineering is like the CENTO Nucelar Centre at Teheran University.

However, it is felt that the foregoing illustrative set of strategies, if not exhaustive, is at least representative of basic strategies employed at the international, regional, and national level. After a few selected country R & D patterns have been considered in the next section, referring to these strategies where applicable, some relationships between objective, strategies, and patterns will be examined in Chapter IV.

Source of Information:

Asociacion Nacional del Cafe, Informe Annual Del Departamento de Asuntos Agricolas: 1963-1964 (Guatemala: April, 1964).

III.4 Country R & D Patterns

III.41 The General Model

In Strategies and Patterns for the Organization of Applied Research in Latin America and South and Southeast Asia,[1] a "pattern" was defined as a combination of all the significant strategies used in a particular developing country to establish and maintain R & D capabilities. Thus a preliminary classification of R & D patterns in terms of R & D strategies was made in that paper, using the general framework shown in Figure 2. Accordingly, countries are shown to be following Pattern P1 which consists primarily of Strategies S1, S2, and SN. In the overall study, data (which are becoming increasingly available) are being collected to extend this preliminary comparative analysis.

It is also important, during this process of collecting data on all developing countries, to examine some of the major country R & D patterns in more depth than is possible in the schematic of Figure 2. This will help us avoid the pitfall of superimposing a too-rigid system of classification on all countries. At the same time, we will place emphasis on the unique characteristics of a given country, as well as allowing for the discovery of new points of comparative analysis. This will be done by examining six country R & D patterns ranging from the simple case of Nepal to the relatively advanced state of organization of R & D in India. Although arranged in order of increasing complexity, this is not meant to imply stages of "evolutionary growth" or similar notions of causality.

The main points included in the description of the country patterns includes:

(1) Background Information
(2) Government Responsibility for Research
(3) University Research
(4) Private and Business Research
(5) Auxilary Scientific Organizations
(6) International Relations in Science

This brief statement of <u>background information</u> includes a few salient features of the economic and social development of the country.

<u>Government responsibility for research</u> includes those obligations which governments actually assumed in order to organize, administer, control, sponsor and/or promote R & D activities.

<u>University research</u> usually includes only those affiliated R & D institutes or similar organizations where research is the prime activity. Graduate research incorporated in degree programs or faculty research which is done in addition to teaching activities are not usually considered. In a few instances, where the country's facilities are extremely limited, e.g. the case of Nepal, additional information is included to gain a better overall view of scientific activity.

<u>Private and Business Research</u> includes all foundations, associations, and corporate research activities which are primarily initiated and sponsored in the private sector.

<u>Auxiliary scientific organizations</u> is a broad category which includes information on organizations not directly engaged in R & D activity, but necessary to its accomplishment, i.e., documentation and information services, industrial liaison and extension, and scientific societies.

<u>International relations in science</u> are the primary links a country has with regional andinternational scientific organizations.

III.42 Illustrative Set of Patterns

III.421 Nepal

<u>Background Information</u>

Nepal, landlocked between India and China, is a nation of over 10,000,000 inhabitants (1963), with over 80% of the people engaged in agriculture and a national literacy rate of about 10%. The main resources include land, forests, and hydroelectricity and some mineral wealth including iron, copper, mica and talc but no coal or oil. The extremely high mountains make both

Figure 2: RELATIONSHIP BETWEEN STRATEGIES AND PATTERNS FOR ESTABLISHING AND MAINTAINING APPLIED RESEARCH (R&D) CAPABILITIES IN DEVELOPING COUNTRIES

			Pattern Number		
			1	2	3
			Country a Country b Country c	Country d	
Strategy Number	Description of Strategy	Sponsor or Sponsor-Client			
1	Liaison between an established research institute in a developed country with a new one is a developing country	XYZ Research Institute in Country W	x		
2	Single-purpose institute established by the national government	Ministry of Agriculture	x	x	
3				x	
o			x		
o					
o				x	
o					
o			x		

Source: Albert H. Rubenstein and Earl Young, "Strategies and Patterns for the Organization of Applied Research in Latin America and South and Southeast Asia" (unpublished, Industrial Engineering and Management Sciences, Northwestern University, 1964).

land and air transportation difficult, resulting in the isolation of much of the population.

The relatively primative state of economic development has led the government to concentrate on infrastructure development including administrative machinery, means of transport and communications, surveys and statistics, and land reform. In the field of education the emphasis is on primary and secondary education.

Government Responsibility for Research

There are no government agencies devoted to the development of a formal national science policy. The current attitude toward a science policy is indicated in the following statement made by D. M. Amatya, the delegate from Nepal to the Third Regional Meeting of Representatives of National Scientific Research Organization in the South and South East Asia Region:

> "As the government does not yet have a good number of scientific research laboratories and instituteions--private or public--to deal with, the question of an elaborate policy on scientific research does not arise."[1]

This, however, does not mean the need for scientific research is unrecognized. Due to limited resources, the basic emphasis, so far as science is concerned, is concentrated on primary and secondary education in an effort to wipe out illiteracy. At the same time the government gives what assistance it can to the development of the university.

> "There is no program in the plan (current Three Year Plan) for opening a National Scientific Research Laboratory or for any other scientific research activities, independent of the university, not because the Government is not conscious of the great importance of scientific and technological research in the process of economic development, but because they do not have adequate resources." (Amatya)[2]

There is no National Research Organization and the only technical activity undertaken by a government department is the Geological--cum--Mining laboratory in the Bureau of Mines. It was formed with assistance from the United States and today includes ten to fifteen scientists and technicians--geologists, chemists, and mining engineers--who work on analyses of indigenous ones and minerals on a routine basis.

University Research

The state of university research is best summarized by D. M. Amatya:

> "Though there are already a few Ph.D.'s in the various sciences in the country, they are not in a position to put into practice the training they acquired abroad because of the absence of any facilities for doing scientific research. There is no accomodation and very little in the way of apparatus and equipment. They are looking forward to the time when post-graduate teaching in the sciences will start at the university and there will be some scope for carrying out research activities in the university departments. But that is as yet a distant possibility."[3]

Science is emphasized in the primary schools and the 570 secondary schools; there are three science colleges, only one of which teaches through the Bachelor of Science level. There is one university gradually being developed which was scheduled to begin graduate work in 1965 in the pure sciences. At the college level, the staff (in 1964) includes 9 Ph.D's 30 M.S.'s and 20 B.Sc.'s with some additional help through the Columbo Plan and Peace Corps. Each year about 50 students are graduated with a B.Sc. degree and 150 with an I.Sc. (equivalent to junior college level).

The university is the focal point of attention in Nepal's development of scientific research:

> "At present all hopes for true scientific research are concentrated in our infant university. As the country cannot afford to fritter away its slender resources--and there is a host of competing projects of high priority claiming for attention and allocation of funds--it will be wise for the country to concentrate its efforts and expenditures for the development of scientific research in one place, and that obviously is the university. All donations and grants from private foundations, governments and international organizations for the purposes of the development of scientific research in Nepal should, if they are to produce the best results, be concentrated in Tribhuban University" (Amatya).[4]

Although Nepal is primarily an agricultural country, there is no agricultural college or forestry training college; it is one of the priority items in the plan of development of the university. Also, there is no college of engineering; students are educated abroad.

Business and Private Research

There is little industry and no industrial research; in fact, the hundred or so engineers in the country are inadequate to accomplish the desired development projects.

Auxiliary Scientific Organizations

Little has been done in this area, i.e.,

> "As there is very little research going on in the country today, the questions of documentation does not arise. There is not even a satisfactory collection of scientific periodicals and journals in our libraries, though there may be some haphazard collection here and there." (Amatya).[5]

The Nepal Science Association was formed with the objectives of fostering the growth of scientific research and to create a climate of cooperation and collaboration. Its membership includes scientists, engineers, doctors, technologists and technicians. However, the Association does not have a laboratory and "it does not have any clearly defined program of scientific activities" (Amatya).[6]

One other association for thepromotion of science has been established, the Tri-Chandra College Science Association. Its membership is small but includes some of the best scientists in the country. It is, however, limited to the college staff. Its chief aim is to foster the growth of the scientific spirit and free inquiry.

International Relations in Science

Most of the international relations in science are formed for the accomplishment of specific projects such as the Geological Laboratory for the Government of Nepal which the United States Government helped establish. The United Nations Special Fund is assisting in basic survey projects such as the hydroelectric potentialities of the Karrali River Basin in Western Nepal, but these projects are not directly geared to increasing the R & D capability of Nepal.

Source of Information:

"Report on Science Education and Scientific Research in Nepal," a report prepared for the Third Regional Meeting of Representatives of National Scientific Research Organizations in the South and South East Asia Regions, Canberra, February, 1964.

III.422 Guatemala

Background Information

Guatemala is the most populous (approximately 4,000,000) and second largest of the Central American republics. The primary source of national wealth has always been agriculture. Coffee is the major crop, providing up to 80 percentof the national income. The banana industry, second in importance, provides 10 to 12 percent of the export income. Until recently there was little manufacturing industry; that which existed was based primarily on food production. The formation of the Central American Common Market has increased industrial activity and caused an increase in foreign investment in the area.

Government Responsibility for Research

Guatemala does not have a formal national science policy such as is noted later in the case of India or the Philippines. Various government agencies, in working on economic and social development, frequently set up objectives which require research and this is one of the most direct but not rigorously organized methods by which the government plans research activities. For instance, the Agronomy section of the Institute de Formeto de la Production (INFOP) works closely with the Instituto Agropecuario Nacional (IAN) which experiments in crop and livestock improvement. INFOP objectives include increasing soybean, fiber, and cotton production; economic manufacture of oil from the corozo nut; and improvement in dairy and livestock production.

The Instituto Agropecuario Nacional (IAN) has four research stations with crop improvement programs in corn, beans, rice, coffee, potatoes, and fruit; a soils and chemical laboratory; and a special crops division for rubber, cacas, blackpepper, and vanilla. Experimental research is not carried to the theoretical level as in Mexico, but it is geared to improving varieties as soon as possible and distributing the results.

Government industrial research is conducted at the Instituto Centroamericano de Investigacion y Technologia Industrial (ICAITI), a regional cooperative institute established in cooperation with the United Nations Special Fund. (This institute was described in more detail in the preceding section on research strategies.)

The government sponsors research in nutrition and public health through the Institute of Nutrition of Central America and Panama (INCAP), also described in the previous section on research strategies.

University Research

Currently there is no organized program of technological research at the University of San Calos. The primary mission of this institution is regarded as teaching and research that is done is incorporated in this objective.

Business and Private Research

In 1964, a significant event occurred in the Guatemalan governments' policy toward research when it allowed the Association of Producers of Essential Oils to use the export duty on these oils, which amounted to $200,000 annually, as a fund for research. The industry employs 20,000 workers and export volume is about $10,000,000 annually making this a relatively important sector of the economy. The new research program, beginning in 1964, will be quite extensive and cover all phases from planting to final markets including selection of crops, addition of legumes, mechanical harvesting, pest control and local fractionating.

Another association conducting research in Guatemala is the Coffee Growers Association, described in the previous section. Currently, very few industrial firms conduct research themselves, but gradually enterprises are increasing their use of ICAITI. Some of the food companies do some research from time to time on specific projects such as the brewery - Cerveceria Centro Americana - which recently completed a five year program to find improved barley varieties. Currently, barley is imported and the company wanted an alternative source of supply to avoid vulnerability to foreign exchange rates.

Auxiliary Scientific Organizations

There are no specialized agencies for the implementation and dissemination of scientific information; each institution is responsible for its own program in this regard. For instance, the Institute Agropecuario Nacional maintains thirty-one stations for agricultural extension services; the Institute of Nutrition and the Central American Institute of Industrial Technology (ICAITI) maintains libraries and information services and ICAITI has an extension pilot plant.

In addition, there are a few associations of the scientific and technical professions as the Associacion de Ingenieros y Arquitectos de Guatemala, Observatorio Nacional Meteorologico y Sismologico; and the Sociedad de Ciencias Naturales y Farmacia.

International Relations in Science

One of the most recent, and in the long run potentially most important, organizational innovations in Central America is the Central American Common Market. Numerous regional organizations are cooperating in many phases of economic, social, and political cooperation. In the area of research two were already mentioned: the Institute of Nutrition (INCAP) and ICAITI. The enthusiasm for regional cooperation is generating interest among foreign investors who see a potential common market of 12,000,000 people with one of the highest birth rates in the world, i.e., almost 3%. Large firms such as ESSO Standard Oil S.A., Ltd., and Shell International Chemical Company, Ltd., are currently studying ways to increase the use of fertilizers in Guatemala. No research activities are currently (1964) being undertaken in Guatemala, but Esso is doing some experimental work with fertilizers in El Salvador, while Shell operates an experimental farm in Venezuela. Results from these activities and other facilities of these international companies are available to the Guatemalan subsidiaries. Both companies have full time agronomists on their staffs to aid in current extension work. Admittedly, this channel of technological imports from international corporations is more of a potential today in Guatemala than an accomplished fact. However, the success of the common market is now attracting these larger international firms capable of greatly increasing technological imports.

International organizations such as FAO (The Food and Agricultural Organization)and the Rockfeller Foundation have projects in Guatemala. FAO works through the Expanded Technical Assistance Program of the United Nations on milk and cotton production and nutrition. Individual research products are carried out by experts in these areas. The Rockfeller Foundation is currently assisting the Department of Agriculture is setting up a program in agricultural research at a new experimental station.

Source of Information

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Esso Agricola. Coral Gables, Florida: Esso Standard Oil S.A. Limited.

Informe Preliminar Institutos de Investigacion Technologica en La America Latine. Prepared by the Division de Technologia y Productifidad, Departmento de Asuntos Economicos, Union Panamericana, Washington, D. C., 1962.

Instituto Centro Americano de Investigacion y Technologia Industrial. Central American Research Institute for Industry. Guatemala.

Shell Public Health and Agricultural News. Vol. 3, No. 2; London: 1960.

World of Learning. 15th edition, 1964-65, editors Europa Publications Ltd. Rochester, Kent, Great Britain: Staples Printers Ltd., 1964.

III.423 Kenya

Background Information

Kenya, a former British colony in East Africa with a population of 8,672,000, is principally supported by exporting coffee. Other important exports include tea, pyrethrum, and sisal; some copper is exported but mineral wealth does not appear great. The country was formerly a part of the territory included under the authority of the East African High Commission, a loose administrative affiliation that also included Uganda and Tanganyika. On December 9, 1961, Kenya became independent and the East African High Commission became the East African Common Services Organization (E.A.C.S.O.). It is through this organization that much of Kenya's research is organized and controlled.

Government Responsibility for Research

Research activities of EACSO are directly responsible to the three participating governments and might properly be considered a form of government research. However, they are also a form of international cooperation at the regional level and are discussed as such later. Direct government research is conducted in the various ministries including the Ministry of Industry, Commerce, and Communications, Ministry of Agriculture and Animal Husbandry, Ministry of Natural Resources, and the Ministry of Works.

With the exception of the Ministry of Agriculture and Animal Husbandry, the research work of these organizations is on a small but diversified basis as can be noted in the following brief statements:

(1) The Mines and Geological Department of the Ministry of Industry and Commerce maintains laboratories and activities that include geological survey, seismography, geochemistry and mineral dressing.

(2) The Forest Department of the Ministry of Natural Resources conducts research in oriented fundamental and applied research in silviculture, entomology, and forest pathology with a staff of five research workers.

(3) The Game Department of the Ministry of Natural Resources has two of its staff working on fauna research.

(4) The Materials Branch of the Ministry of Works has five research workers and ten technicians working on several aspects of building and civil engineering.

In contrast, the Ministry of Agriculture and Animal Husbandry has an extensive research program and a history which dates back to 1903 when the Department of Agriculture acquired its first experimental farms. Its major units are listed in Figure 3. Of special interest are the commodity stations for coffee, cotton, pyrethrum, sisal and sugar which have as a major objective the improvement of the crop yields through systematic study of all phases of the production cycle. The only major crop not included in this group is tea; research on this crop is conducted by a private institution (see below).

University Research

The University of East Africa was formed in 1963 incorporating Makerere University College of Uganda, the University College of Tanzania and the University College of Kenya. Research is conducted as a part of teaching by the Faculties of Engineering and Sciences. Some research also conducted by Egerton College which owns its own experimental farms.

Business and Private Research

The Tea Research Institute of East Africa is a private institution which maintains a staff of three research workers and five technicians principally in applied research.

The Pyrethrum Board of Kenya is a private institution engaged in oriented fundamental and applied research. It maintains a laboratory and a staff of four research workers primarily in plant chemistry.

Auxiliary Scientific Organizations

There are no specialized auxiliary scientific organizations; each institution assumes responsibility for the procurement of scientific information and the utilization of scientific results. In this regard the East African Agriculture and Forest Research Organization Library in Kikuyar is noted; the library contains over 20,000 volumes. There are no indigenous scientific socieites.

International Relations in Science

Although regional in the scope of its activities, E.A.C.S.O. is directly accountable to each of the governments of the participating countries and as such is one of the most significant regional cooperative efforts in the developing countries. Responsibility for the organization rests with the East African Common Services Authority composed of the principal Ministers of the three territories supported by five groups of three ministers each, one from each

FIGURE 3

KENYA GOVERNMENT
DEPARTMENT OF AGRICULTURE

National Agricultural Research Laboratories, Nairobi
- Chemistry Section
- Plant Pathology Section
- Entomology Section

National Agricultural Research Station, Kitale
- Kitale Agricultural Research Station
- Maize Improvement Unit

General Investigation Stations
- Nyanza Agricultural Research Station, Kisii
- Western Agricultural Research Station, Kakamega
- Animal Husbandry Section, Nakuru
- Elderet Agricultural Research Station
- Marindas Agricultural Research Station, Molo
- Nyandarua Agricultural Research Station, Ol Joro Orok
- Embu Agricultural Research Station
- Katumani Agricultural Research Station, Machakos
- Coast Agricultural Research Station, Kikambala

Horticultural Research Stations
- Horticultural Research Station, Thika
- Horticultural Research Station, Molo

Plant Breeding Station, Njoro

Commodity Stations
- Coffee Research Station, Jacaranda
- Cotton Research Station, Kibos
- Pyrethrum Research Station, Molo
- Pyrethrum Research Unit, Ol Joro Orok
- Sisal Research Station, Thike
- Sugar Research Unit, Kisumu

Irrigation Research Units
- Kano Irrigation Research Station, Ahere
- Mwea-Tebere Irrigation Research Unit, Embu
- Perkerra Irrigation Research Unit, Marigat
- Tana Irrigation Research Unit, Galole

Source: Department of Agriculture, Kenya, Descriptive Notes on all the Stations and Units in the Research Division, 1964, p. 1.

country. These five groups include communications, finance, commercial and industrial coordination, labor, and research. EACSO administers fourteen research groups, several of which have headquarters in Kenya.

(1) The East African Agriculture and Forestry Research Organization was founded in 1948 and is located in Muguga near Nairobi. Its activities include the planning of research, soil science, plant physiology, plant genetics, breeding, forestry and forest entomology, systematic botany, and animal husbandry.

(2) The East African Meterological Department, founded in 1929 with headquarters in Nairobi, has a high reputation internationally and has pioneered in the adoption of modern techniques in Africa. It has developed new methods for meterological analysis and weather forecasting in equatorial region; techniques for artificial stimulation of rainfall; and prevention of hail and evaporation from dams. Nearly all of its research is of fundamental importance to the economy of East Africa.

(3) The East African Trypanosomiasis Research Organization also headquartered in Nairobi and founded in 1949 works on tests and trypanosomiasis research and reclamation for both humans and animals.

(4) The East African Veterinary Research Organization founded in 1948 in Kikuya prepares and issues biological products and conducts research into animal health and animal diseases.

(5) The East African Industrial Research Organization was established in 1942 to undertake applied research for industries in East Africa which are in the course of development and also to give technical assistance and advice to established industry on day to day problems. The primary orientation of the laboratories and pilot plant is toward agricultural processing research. Outside of the Union of South Africa, the East African Industrial Organization was one of the first highly developed industrial research organizations in Sub-Saharan Africa.

(6) The East African Statistical Department is located in Nairobi. Besides EACSO research activities in Kenya, the organization has these research organizations in Tanzania and Uganda:

a) Marine Fisheries Research Organization (Tanzania)
b) Institute of Malaria and Vector-borne Diseases (Tanzania)
c) Institute for Medical Research (Tanzania)
d) Tropical Pesticides Research Institute (Tanzania)
e) Freshwater Fisheries Research Organization (Uganda)
f) Leprosy Research (Uganda)
g) Virus Research Institute (Uganda)
h) Institute of Social Research (Uganda)

The Desert Locust Control Organization of East Africa located in Nairobi was formed in 1962 as the successor to the Desert Locust Survey. It is governed by an International Council composed of representatives of Kenya, Tanzania, Uganda, Ethiopia, and the Somali Republic, and works through the EACSO.

In 1950 the Commission for Technical Cooperation in Africa South of the Sahara (CCTA) was established to ensure technical cooperation between members. Originally, the prime movers were the various colonial powers especially the United Kingdom and France. In 1963, the Organization for Africa Unity, an organization set up by the Heads of State of a large number of independent African countries met to take over the CCTA. The CCTA had established several cooperative ventures to increase scientific cooperation such as the Inter-African Bureau for Animal Health located in Kenya. This bureau was established in 1951 as an intergovernmental agreement between twenty-five governments South of the Sahara. Its primary function is the communication of research results on animal diseases; facilities include an extensive reference library; and the staff includes four scientists.

Source of Information

Department of Agriculture, Kenya. Descriptive Notes on all the Stations and Units in the Research Division.

East African Common Services Organization. Kenya: Government Printer.

East African Common Services Organization, Annual Report 1963. Kenya: Government Printer, 1964.

East African Common Services Organization. East African Industrial Research Organization Annual Report 1962-63. Kenya: Government Printer.

East African Common Services Organization. East African Meterological Department: Annual Report for 1962-63. Kenya: Government Printer, 1964.

Inter-African Bureau for Animal Health Twelfth Annual Report: 1963. Kenya: 1964.

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World of Learning. 15th edition, 1964-65, editors Europa Publications Ltd. (Rochester, Kent, Great Britain: Staples Printers Ltd., 1964).

III.424 The Philippine Islands

Background Information

While the Philippine Islands are made up of 7,100 islands, the population of approximately 28,000,000 is concentrated on the three largest island groups of Luzon, Mindanao, and Visayas. Sixty percent of the population is engaged in agriculture. The main crops are rice, Manila hemp, copra, sugar cane, maize, and tobacco; in addition, there is a large timber production for export. Copper, iron, and chromite ores are also exported. The 1960 GNP was $3.14 billion.

There were a few early efforts by the Spanish during the years of colonization to introduce scientific experimentation, but it was not until the American period of control (1898-1946) that science was seriously brought to bear in problems of economic and social development. The Bureau of Government Laboratories established in 1901 becaue the Bureau of Science in 1905. In 1933 a National Research Council was established; in 1952 the Science Foundation of the Philippines was set up for the promotion of research from private grants and donations; in 1956 the National Science Board was established and reorganized in 1958 and the National Science Development Board was formed. The old Bureau of Science, which had been changed to the Institute of Science under the office of the President in 1947, was set up as the National Institute of Science and Technology under the National Science and Development Board.

Government Responsibility for Research

The organization chart of the National Science Development Board (NSDB) is shown in Figure 4. The NSDB is the chief scientific policy making group in the country and its Chairman holds cabinet rank. The formulation of national science policy by the NSDB in a four-stage operation: inventory; assessment; programming; and strategy. In the inventory stage, information about the national science resources is collected, compiled, and analyzed:

> "This activity includes a survey of the research and development activities of both the Government and Private sectors; surveys of facilities for science education in instutions of higher learning, studies on status of and trends in research in the major disciplines of science; surveys and studies of production and utilization of scientific and technical manpower" (Oldham).[1]

Inventory work also includes studies of relevant foreign material, such as the formulation of national science policies and the technological developments that could be adapted locally.

The assessment stage is handled by a staff of scientists that identify trends in major scientific fields (see Figure 4) and then make decisions on the desirability of changes or shifts in trends. Based on these assessments the actual programming of activities is undertaken. A major task is to gear these scientific activities to the Governments' Five Year Integrated Socio-Economic Program for the Philippines. At this stage fundamental decisions are are made on such questions as:

> "Should priority be given to support research or to manpower development?"
> "Of the research to be done, how much support should be given for basic research and how much for applied?"
> "Of the applied research, which should receive most support, industrial research, agricultural research, or medical research?" (Oldham)[2]

Decisions are made on the over-all objectives of the science program and a preliminary plan of action is arrived at based on a comparison of projected trends of science development and the desired scheme of priority actions. The next task, the choice of a strategy involves the formulation of specific allocations of resources and determining incentives for the private sector.

> In summary, "the result of all these activities is a statement of an objective, and a plan of action to reach this objective. These constitute a policy, and are incorporated in the NSDB Five-year Science and Technology Development Program. The policy is implemented by researches carried out by the various research centers of the National Institute of Science and Technology (NIST) and the Philippine Atomic Energy Commission (PAEC), other Government agencies and by grants to the private sector, inclluding universities" (Oldham).[3]

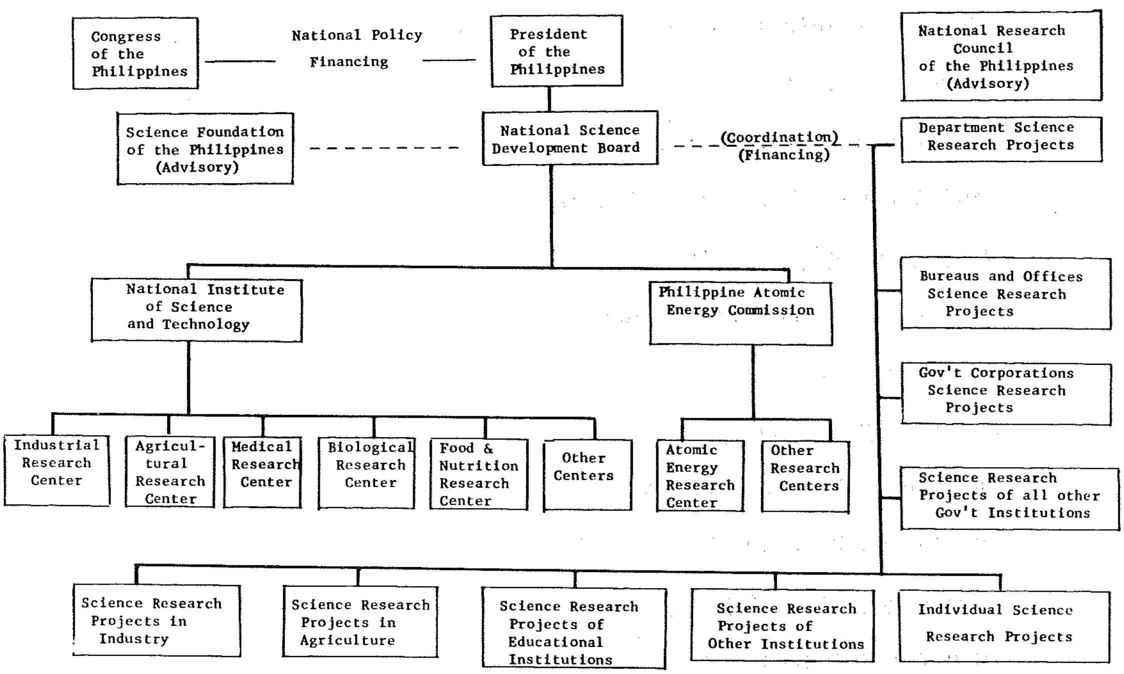
The government agencies performing research are shown in Figure 5, in 1960 these agencies spent a total of $3,180,000 on R & D. The Department of Agriculture and Natural Resources spent $1,630,000 of this total and the NSDB spent $920,000. Applied R & D funds which accounted for 88% of the total, was divided as follows: Agriculture 57%, Economic Research 13%, Industrial Research 14%, Medical Research 11%, other 5%. In basic research, social sciences accounted for almost 50% of the expenditures, life scienices 40%, and physical science 12%. In 1960, there were 970 scientists and engineers in R & D employed by the government and 1,420 supporting personnel.

Central Bodies for scientific research include the National Research Council with a membership in 1960 of 546. Many initial functions of the council were transferred to the NSDB freeing the Council to concentrate on basic research. A second central body, the Science Foundation of the Philippines formed in 1952 concentrates on laying foundations for future research by such activities as

FIGURE 4

NATIONAL SCIENCE DEVELOPMENT BOARD

ORGANIZATIONAL CHART



Source: C. H. G. Oldham (Com. by) The Organization of Scientific Research in the Philippines (December, 1963) p. 7.

FIGURE 5

PHILIPPINE GOVERNMENTAL RESEARCH INSTITUTIONS

1. Department of Agriculture and Natural Resources

    Agricultural Economics Division

    Bureau of Fisheries

    Bureau of Forestry

    Bureau of Mines

    Bureau of Plant Industry

    Bureau of Animal Industry

    Bureau of Soils

    Philippine Sugar Institute

    Philippine Tobacco Administration

2. Department of Education

    Institute of National Language

    National Museum

3. Department of Health

    Bureau of Disease Control

    Bureau of Research Laboratories

4. Department of National Defense

    General Headquarters

    Bureau of Coast and Geodetic Survey

5. Department of Public Works and Communications

    Bureau of Public Highways

    Irrigation Service Unit

6. Government Owned or Controlled Corporations

National Development Company

Government Service Insurance System

Central Bank of the Philippines

People's Homesite and Housing Corporation

Cebu Portland Cement Company

7. National Science Development Board

National Institute of Science and Technology

Philippine Atomic Energy Commission

8. Office of the President

Land Tenure Administration

9. Department of Justice

National Bureau of Investigation

Source: C. H. G. Oldham (Comp. by) The Organization of Scientific Research in the Philippines (December, 1963) p. 8.

FIGURE 6

RESEARCH AND DEVELOPMENT EXPENDITURES IN PRIVATE INDUSTRY

BY INDUSTRY GROUP AND BY CHARACTER OF WORK, 1960

(Peso* amounts in thousands)

Industry Group	Total	Basic Research	Applied Research & Development
TOTAL	₱7,712	₱750	₱6,926
Food and kindred products	1,318	437	881
Beverages	32	-	32
Textiles	39	2	37
Wood and cork products	308	169	139
Paper and paper products	73	-	73
Leather	31	-	31
Rubber products	1,229	4	1,225
Chemicals and chemical products	845	45	765
Non-metallic mineral products ...	220	-	220
Metal products except machinery and transport equipment	69	23	46
Machinery except electrical ...	223	21	202
Electrical equipment	744	21	723
Transport equipment	48	-	48
Other manufacturing industries ...	86	5	81
Non-manufacturing industries ...	2,450	23	2,424

*Exchange rate in 1960: Peso Equivalent to $.263 (U. S. Dollars)

Source: C. H. G. Oldham (comp. by) The Organization of Scientific Research in the Philippines (December, 1963) p. 10.

promoting science consciousness and science teacher training. Lastly, the Philippine Academy of Sciences and Humanities was formed in 1961 and is patterned after other national academies, especially the American academy.

University Research

There are twenty-five institutions which qualify as universities in the Philippines, i.e., by definition in the Philippines those institutions which conduct research. In practice, there is little actual research undertaken with two exceptions. The State-owned University of the Philippines at Los Banos is noted for its research in the College of Agriculture and the College of Medicine. Secondly, the Attenco de Manila operated by Jesuit priests does basic research in geophysics at the Manila Observatory.

Business and Private Research

In 1960, the private sector spent a little over $2,000,000 of which 90% was for applied and 10% for basic research. The breakdown by industry (see Figure 6) shows the non-manufacturing industrial group spends the most with expenditures of approximately $600,000; the food industry is second with almost $350,000; and the rubber industry third with about $320,000. An NSDB survey in 1960 showed that industry employed 312 scientists and engineers in R & D, supported by 766 personnel. Of the scientists and engineers, 20% were employed by the chemical industry and 17% by the food industry. There are no cooperative research associations but many of the companies are subsidiaries of large foreign corporations and import technological advances through the parent company. Foundation sponsored research includes the International Rice Research Institue described in the preceding section.

Auxiliary Scientific Organizations

In 1958, with the aid of UNESCO the Division of Documentation of the National Institute of Science and Technology was formed as the sucessor to the pre-war Division of Scientific Library of the Bureau of Science. The Institute is both a library and documentation center and also has the function of disseminating scientific information. Four publications are issued by the Division: (1) Philippine Abstracts; (2) Philippine Series of Specialized Collections of Abstracts; (3) Series of Philippine Scientific Bibliographies; (4) Philippine Technical Information Sheets.

The NSDB has a Science Pavilion and Planetarium with facilities for conferences and lectures, and each year the Board sponsors a science and technology week. The NSDB publishes the Philippine Journal of Science quarterly and the Science Review monthly. The Science Bulletin is published quarterly by the Science Foundation for Teachers.

Science information offices have been established throughout the country by the NSDB. Also, several socieites especially the Societies of Biology, Chemisty, and The Society for the Advancement of Science, disseminate scientific information.

International Relations in Science

The National Research Council represents the Philippines in non-governmental international scientific relations; it is also the Philippine organization belonging to the International Council of Scientific Unions. Of the fifteen member unions, the Philippines are only active in the International Union of Geodesy and Geophysics. The Department of Foreign Affairs handles international scientific relations with governmental organizations, but the NSDB has an Office of International Science Relations which arranges for visits and conferences between scientists from foreign countries in the Philippines. Science attaches have been established in Washington, D. C. and Bonn. Technical assistance is coordinated with national planning by NSDB.

Source of Information:

Oldham, C.H.G. (compiled by). The Organization of Scientific Research in the Philippines. December, 1963.

Five Year Science and Technology Development Program 1962-3 to 1966-7. Manila: NSDB.

Senate Committee on Scientific Advancement, Report on the Problem of Science in the Philippines. Manila: 1963.

The National Science Development Board and Higher Education. A report prepared by NSDB, Manila.

World of Learning. 15th edition, 1964-65, editors Europa Publications, Ltd., Rochester, Kent, Great Britain: Staples Printers Ltd., 1964.

III.425 Mexico

Background Information

Mexico with a population close to 40,000,000 is the second most populous country in Latin America and the third largest in the area. It is significant as a leader in the hemisphere for reasons besides size: "It has met and successfully surmounted many of the social, economic, and political problems which face most of the countries of Latin America--indeed most of the countries of the world" (Needler).[1] Due to mountainous terrain, forests, and desert, only about one-third of the country is suitable for agriculture, much of this with irrigation. Industry has steadily increased especially since World War II, and today approximately one-half of the population is urban. Illiteracy has dropped to about 37 percent and is steadily falling. Control of the economy is mixed with ownership largely private but with the government active in promoting development and occasionally taking over the ownership of firms or industries. The economy is well diversified, but the two major crops, cotton and coffee, account for one-third of the country's exports by value.

Government Responsiblity for Research

The Mexican Government does not incorporate a detailed plan for R & D in its development machienry, but the importance of research is recognized and fostered in the various departments and agencies. The following information is not intended as a complete inventory of departments engaged in research; it does cover some of the most important of these departments insofar as it was possible to determine during the brief field study made by the author during the summer of 1964.

(1) The Comision Nacional de Energia Nuclear is primarily interested in the peaceful use of nuclear energy for industrial, medical, agricultrual

and energy purposes. Mexico has little coal but much oil. However, the government does not want to burn it all as fuel and also they look to the future when oil resources will be depleted. Currently, they are working with Pemex, the government oil monopoly, on some limited industrial research. Other institutional agreements include the University of Mexico, the National Polytechnic Institute and other universities. In 1964, ground was broken for a new nuclear energy center south of Mexico City, and many of the facilities now located throughout the city will be brought together when the center is completed.

(2) The Consejo de Recursos Naturales no Renovables has the responsibility for studying the non-renewable natural resources of Mexico with the following objectives:

a) evaluating the mineral wealth of the nation
b) investigating new deposits
c) developing marginal mines
d) studying the processing of minerals within the country
e) studying the industries connected with the minerals.

Each of these activities requires some research activities and the council maintains a large central laboratory in Mexico City. The council, as the Nuclear Energy Commission, works with many other institutions, both governmental, private enterprise, and universities.

(3) The Instituto Nacional de Investigaciones Agriculturas (INIA) was set up within the Ministry of Agriculture with the assistance of the Rockfeller Foundation (see Mexican Agricultural Programs of the Rockfeller Foundation in preceding section). INIA devotes two-thirds of its efforts to applied research and the balance to basic research. Primary emphasis is on developing crops best suited to the several widely differing geographic regions. The institute operates on a fixed annual budget but is free to determine their use. In addition to basic food crops, INIA does research on domestic industrial crops and export crops; only sugar, of the export crops, has any significant private research. The Instituto Nacional de Investigaciones Forestales (INIF) is also a part of the Ministry of Agriculture. In 1961, INIF received a grant from the United Nations Special Fund for a national inventory of the forests of Mexico. Today this project, under the joint sponsorship of a United Nations Special Fund, FAO, and the Mexican Government, has successfully completed the major portion of its initial program and it is currently used as a "showcase" project by FAO. An extensive program of cooperation is carried on with the University of Mexico, the National Polytechnic Institute, and the National School of Agriculture. Research activities at INIF breakdown into three major groups: inventory, wood technology, and silviculture and each of these, in turn, is in process with an average of six or seven of the staff abroad in Europe or the United States at any one time; this is out of a staff of 45 to 50.

(4) The government oil monopoly, Petroleos Mexicanos (Pemex) through its Office of Coordination and Technical Studies has a few sporadic research projects, but primary emphasis is on production and technology is imported by licensee agreements with U.S., French, and German firms.

(5) The Instituto Nacional de Investigacioas Cientificas does not conduct research directly; it is a governmental agency for disbursing funds as student loans, and subsidies for laboratory facilities. Currently, there are 150 students on this program, one-half of them abroad. The emphasis is on smaller universities and colleges which have no access to other sources of funds.

University Research

University education dates back to 1551 when the Universidad Nacional Autonoma de Mexico was founded with classes commencing in 1553. Research in the physical and life sciences is of much more recent origin and there are several affiliated research institutes in the Instituto Ciencias de Universidad a Mexico. These include:

(1) The Observatorio Astronomico
(2) Instituto de Biologia
(3) Instituto de Estudios Medicos y Biologicos
(4) Instituto de Fisica
(5) Instituto de Geofisica
(6) Instituto de Geologia
(7) Instituto de Matematica
(8) Instituto de Quemica

Recent additions include an Institute for Oceanography and a Center for Computers. Currently, the institutes together have 150 at the Ph.D. level doing research and teaching a maximum of six hours; at the Master's level there are 150 doing research on a half-time basis. The University works closely with the government and other universities on research programs.

The Instituto Politecnico Nacional was founded in 1936 and concentrated on teaching activities. On July 5, 1963 the Centro de Investigacion y de Estudios Avanzados of the Instituto Politecnio was commemorated. Fundamental research is done in departments of mathematics, physics, electrical engineering, physiology and biochemistry.

In 1943 the Instituto Technologico y de Estudios Superiores de Monterry was founded. Applied research is conducted primarily in chemical engineering which accounts for 65 percent of the research work; the balance is in agronomy, other fields of engineering and metallurgy.

The Escuela National de Agricultura was established in 1859 as an undergraduate school, but the graduate school was not established until 1959. It is located at Chapingo south of Mexico City. INIA and the Agricultural Extension Service will move to Chapingo to make one of the largest centers in Latin America for agricultural studies including teaching, research, and extension. Research in the graduate school is done in coordination with INIA, and care is taken not to duplicate experiments so that graduate work can be of direct use in the economic development of the country.

Business and Private Research

The most important private organization for industrial research is the Instituto Mexicano Industrias Technologicas founded in 1950 in cooperation with the Armour Research Foundation (now IIT Research) of the Illinois Institute of Technology. IMIT is sponsored by the Banco de Mexico with 51% of the stock government owned; the Nacional Financeria with a majority of stock also controlled by the government; and the Banco Nacional de Comercio Exterior controlled by private sources. One-third to one-half of the projects are received from clients and the balance initiated as "bank" projects or in-house research. Projects are preferred which will aid the economic development of the country, and on in-house projects two major criteria are used in selecting projects. These are the amount by which imports can be reduced and the dollar volume involved. Initially some of the staff was provided by Armour Foundation, but IMIT has been staffed for several years by Mexican scientists and technicians. During the first five to eight years of the organizations existence, growth was slow and efforts were concentrated on three problems: (1) training a staff, (2) developing an orientation, (3) justifying the existance of the organization to sponsoring agencies. During the last five to eight years the organization has been generally accepted and is growing more rapidly, adding facilities, and increasing the amount of client-sponsored research.

As previously mentioned, the only significant private research on a commercial crop is done by the sugar industry. This research is done cooperatively by the Union Nacional de Productionas de Azucar and is primarily geared to increasing productivity.

Branch operation of large industrial firms are beginning such as Colgate-Palmolvie which maintains applied R & D facilities primarily for new product development for the Mexican market and process and product improvement, while more basic research is done in the United States. One interesting aspect of the Colgate laboratory which has a more general application is the technical assistance they have given to Mexican suppliers or potential suppliers in upgrading raw materials to meet more rigid specifications.

Mexican firms are also beginning to institute R & D programs; an example is Resistol, a company which manufactures adhesives and which budgets for R &D as a percent of sales. Of course, Sintex, a private firm that specializes in the manufacture of pharmaceutical products, is an outstanding example of a Mexican firm doing basic and applied research on a large scale in Mexico.

Auxiliary Scientific Organizations

Several scientific socieites have been formed in Mexico including:
(1) The Sociedad Geologica founded in 1904 with 327 current members;
(2) The Sociedad Matematica founded in 1943 with 250 current members;
(3) The Sociedad Mexicana de Antropologia founded in 1937 with 165 current members;
(4) The Sociedad Botanica founded in 1941 with 130 current members;
(5) and The Sociedad Forestal founded in 1921 with 75 current members.

Other societies include:
(1) The Academia Nacional de Ciencia
(2) The Academia Nacional de Medicina de Mexico
(3) Asociacion de Ingenieros y Arquetectos de Mexico
(4) Asociacion de Mexicana de Geologos Petroleros
(5) Ateneo Nacional de Ciencias y Artes de Mexico
(6) Instituto Nacional de Higiene
(7) Sociedad Astronomica de Mexico
(8) Sociedad de Estudios Biologicos
(9) Sociedad Mexicana de Biologia

International Scientific Relations

The Mexican Government cooperates closely with the specialized agencies of the United Nations on such projects as the national forest inventory, and private foundations such as the Rockfeller foundation on a program in the agricultural sciences. Also, several U.S. universities are currently working with schools in Mexico on long term cooperative programs.

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III.426 India

Background Information

Scientific research was initiated on the Indian sub-continent much earlier than most developing regions due to the British influence. In 1851, the Geological Survey was established with the primary purpose of preparing a geological map of India and an appraisal of the country's mineral deposits. Agricultural research began in 1889 at the Central Veterinary Research Institute of Poona, and in 1903 a Central Agricultural Institute was formed. Medical research has a long tradition dating from 1845 when Major Dempster investigated malaria; in 1912, the Indian Research Association (now known as the Indian Council for Medical Research) was founded; in 1921, the school of Tropical Medicine was established at Calcutta; and in 1925, the Nutritional Research Laboratory at Coonoor. In 1942, the Council of Scientific and Industrial Research, CSIR, an autonomous non-official organizatinn to promote and coordinate scientific and industrial research was established and these along with the CSIR are responsible for almost all research institutes; these are the Indian Council of Medical Research in 1911., and the Indian Council of Agricultural Research (CAR) in 1929. These are discussed in greater detail below.

Government Responsibility for Research

As the first developing country to coordinate a science plan with a national development plan, India has developed a comprehensive science policy. The general aims of this policy are:

(1) To foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects--pure, applied and educational;

(2) to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation;

(3) to encourage, and initiate, with all possible speed, programs for the training of scientific and technical personnel, on a scale adequate to fulfill the country's needs in science and education, agriculture and industry, and defense;

(4) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

(5) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

(6) and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

To carry out these goals, there is a developed scientific infrastructure with three Central Government Ministries controlling the above mentioned research councils. The Ministry of Food and Agriculture provides five-year block grants to the Indian Council of Agricultural Research; the Ministry of Health in a similar manner controls the Indian Council of Medical Research; and the Ministry of Education and Scientific Research, the CSIR. These councils which are autonomous use the grants to sponsor research in different institutes and at the universities.

The Indian Council of Agricultural Research (ICAR)

The ICAR does not maintain research laboratories of its own but finances research in central and State research institutions, universities and private laboratories. The six central research institutes include the Indian Agricultural Research Institute, the Indian Veterinary Research Institute, the Central Dairy Research Institute, the Central Rice Research Institute, the Central Potato Research Institute, and the Indian Institute of Sugarcane Research.

Besides these institutes, there are a number of commodity committees for supervising research in cotton, juta, sugar, coconut, tobacco, oilseeds, areca nut and lac. Some of these committees operate their own research laboratories. In addition to government grants, the ICAR obtains revenue from a 'cess' (or duty) on certain commodities such as spices not subject to export duties. The Forest Research Institute and College is a leading center for forestry education and hresearch and specializes in forestry problems in India and neighboring countries. This institute has been used as a training center by FSO of the United Nations for technical training in froestry for Southeast Asia.

The Indian Council of Medical Research

Since medical research is not generally considered within the scope of the long term study governing this thesis, the activities of the Indian Medical Council will not be examined except to note that the Council governs the activities of some research institutes which are in sciences allied to medicine as shown in the following list:

Institution	Location	Work done
The All-India Institute of Hygiene and Public Health	Calcutta	Instruction in preventive and social medicine and research into industrial diseases and waste pollution problems of rivers
The Central Drugs Research Institute	Lucknow	Drug research
The Central Research Institute	Kasauli	Microbiological, serological, and biochemical research
The Pasteur Institute of Southern India	Coonoor	Bacteriology and Pathology
The Nutrition Research Laboratories	Hyderabad, Deccan	Nutrition and allied sciences

The Council of Scientific and Industrial Research (CSIR)

Although the CSIR was founded in 1942, it was only after India gained independence that the Council became a major force for scientific and industrial research. The first National Laboratory was established in 1950 and by 1963 there were twenty-eight laboratories covering many fields of science and technology. Major emphasis is on applied research but basic research is not neglected, i.e.,

> "From the beginning, the Council has recognized that without basic research, there can be no significant advance in knowledge or the development of technology, while without applied research, the country cannot prosper and the theoretical research may degenerate into more academic exercise." (CSIR Activities Survey)[1]

The main functions of the CSIR are:

(1) the promotion, coordination, and guidance of scientific and industrial research in India;
(2) the establishment and maintenance of laboratories for scientific study of problems affecting particular industries and trades;
(3) the establishment and award of scholarships, fellowships, and research grants;
(4) utilization of research results towards the development of industries in the country;
(5) the establishment, maintenance and management of laboratories, workshops, institutes and organizations to further scientific and industrial research;
(6) the collection and dissemination of information in regard not only to research but also to industrial matters generally;
(7) the publication of scientific papers and a journal of industrial research and development.

The CSIR is the main vehicle for implementing the National Science Policy through its various national laboratories (see Figure 7). To carry out its own research programs the staff of the CSIR included 2460 scientists and 3217 technicians in January 1962. The laboratories are closely geared to carry out research directed towards the fullest utilization of India's natural resources for the economic development of the country. Investigations are carried out to the pilot plant stage whenever necessary to establish the feasibility of large scale production. Several comprehensive surveys on the availability and quality of raw materials have been made by the national laboratories. Other aspects of the CSIR are mentioned in some of the following sections.

Other government agencies which conduct research include the Atomic Energy Commission set up in 1948 to develop nuclear energy for peaceful purposes in India. In 1948, the Indian Defense Science Organization was set up to assist the Armed Forces in maintaining and improving their efficiency by carrying out research into various aspects of defense science. In 1953 the Central Board of Irrigation and Power began organized research in irrigation and hydraulic engineering in India; through the Central board a program of coordinated research is carried out in thirteen institutions.

There are other government agencies in the central government which conduct or sponsor research relevant to their functions such as the Railway Testing Center and the Research Department, All-India Radio, Delhi, and the Telecommunication Research Institute at New Delhi. In addition, several state governments run research institutes such as the Jiwaji Industrial Research Laboratory in Gwalier.

The percentage distribution of Central Government expenditure on different sectors of scientific research in the fiscal year 1962-63 was as follows:[2]

Atomic energy	25.90%
Scientific and industrial research	24.02
Defense	12.36
Agricultural research	11.06
Geological survey and mines	6.85
Medicine and public health	5.75
Economic and Statistics	4.85
Irrigation and power	3.63
Veterinary and animal husbandry	2.98
Railways	1.82
Archaeological and anthropoligical	0.79

University Research

In 1964 there was a total of 65 universities and institutes awarding science degrees; in 1962-3 the Ph.D. enrollment in science and technology was 2502 and in 1960-61, 513 Ph.D. degrees were awarded. Grants for research and fellowships were made by the central research councils, and in 1962-63 there were about 1300 research fellows and assistants engaged in research activities financed by the CSIR.

Business and Private Research

The CSIR has been active in promoting cooperative research in industry and as a result the following research associations have been established:

Ahmedabad Textile Industry's Research Association, Ahmedabad
Bombay Textile Industry's Research Association, Bombay

FIGURE 7

NATIONAL LABORATORIES AND INSTITUTES OF INDIA

1. National Physical Laboratory, New Delhi.
2. National Metallurgical Laboratory, Janshedpur.
3. National Chemical Laboratory, Poona.
4. Central Fuel Research Institute, Jealgora.
5. Central Glass & Ceramic Research Institute, Calcutta
6. Central Drug Research Institute, Lucknow.
7. Central Food Technological Research Institute, Mysore.
8. Central Road Research Institute, New Delhi
9. Central Electro-Chemical Research Institute, Karaikudi
10. Central Leather Research Institute, Madras.
11. Central Building Research Institute, Roorkee.
12. Central Indian Medicinal Plants Organization, Lucknow.
13. National Botanic Gardens, Lucknow.
14. Central Electronics Eng. Research Institute, Pilani.
15. Central Mining Research Station, Dhanbad.
16. Regional Research Laboratory, Hyderabad.
17. Indian Institute for Biochemistry and Experimental Medicine, Calcutta.
18. Birla Industrial & Technological Museum, Calcutta.
19. Central Salt & Marine Chemicals Research Institute, Bhavnagar.
20. Regional Research Laboratory, Jummu-Tawi.
21. Central Mechanical Eng. Research Institute, Durgapur.
22. Central Public Health Eng. Research Institute, Nagpur.
23. National Aeronautical Laboratory, Bangalore.

24. Regional Research Laboratory, Jorhat (Assam).

25. National Geophysical Research Institute, Hyderabad.

26. Central Scientific Instrument Organization, Chandigarh.

27. Indian Institute of Petroleum, Dehra Dun.

28. Visweswaraya Industrial & Technological Museum, Bangalore.

Source: "Survey of the Main National Scientific Research Organizations," compiled by C. P. Aggarwal and Shri K. Ramanathan for the Council of Scientific and Industrial Research of India for the Third Regional Meeting of Representatives of National Research Organizations, Canberra, Australia; February, 1964.

South India Textile Research Association, Coimbatore
Silk and Art Silk Mills' Research Association, Bombay
Indian Paint Research Association, Calcutta
Indian Rubber Manufacturer's Research Association, Bombay
Cement Research Institute of India, Bombay
Indian Plywood Manufacturers Research Association, Bangalore
Tea Research Association, Bombay
Wool Research Association, Bombay

In addition to these associations there are several industrial research institutes such as the Shri Ram Institute for Industrial Research, Delhi, which concentrates on short-term industrial research problems having direct application; the Tesco Research and Control Laboratory, Jamshedpar, maintained by the Tata Iron and Steel Company, which does metallurgical research; and the Sen Profulla Chandra Research Laboratory, Calcutta, which carries on applied research in organic, synthetic and biochemical colloids and chemotherapy.

In a survey of science in India[3] in 1964, a total of 91 scientific and technological research institutes were identified besides the national laboratories. These were not identified by sponsorship and presumably could have been government, university, or private institutes. In this survey it was also noted that there were 114 agricultural research institutes and 47 medical research institutes.

Utilization of Research Results

In the Indian Council of Agricultural Research (ICAR) there is a network of organizations coordinated by the Central and State Information Committee which makes research information available.

In the CSIR, the Industrial Liaison and Extension Unit of the Council maintains contacts with Chambers of Commerce and Industry, industrial and trade associations, government departments and other users of research results. The Survey and Information Divisions of national laboratories maintains liaison with industry for promoting the utilization of results developed through research. The Extension Service Unit in CSIR headquarters makes an effort to have research results utilized for the economic betterment of rural communities. The Patents Section of the CSIR assists inventors in drafting specifications and filing patent applications.

Scientific Information Services and Scientific Socieites

The Information Divisions of the national laboratories handle technical inquiries and advise industry, and some of the laboratories issue technical bulletins and periodicals. The Publications and Information Directorate of the CSIR publishes journals, monographs, technical reports, literature surveys and a fortnightly CSIR News.

The Indian National Scientific Documentation Center (INDOC) established with assistance from UNESCO, provides a complete range of documentation services to individuals and institutions throughout the country.

While only four scientific societies existed prior to 1900, the number of societies established accelerated throughout the current century until today there are 189 registered societies. The number of journals now published is 347.

Teachnical Manpower

The CSIR set up the National Register Unit to act as a clearing house of information for technical manpower both on domestic scientists and technologists and Indian scientists in foreign countries. A Scientists Pool has been organized to provide employment assistance and temporary placement to highly qualified scientists, especially those returning from abroad.

International Relations in Science

Each of the three major research councils maintains extensive international relations, especially the CSIR which participates in international research projects such as the International Geophysical Year and the International Quiet Sun Year and the International Indian Ocean Expedition. The Radio Research Committee of the CSIR functions as the National Committee for the International Union of Radio Sciences. INSDOC represents India on the International Federation of Documentation. Some of the national laboratories are working on research projects with UNESCO and the International Congress of Scientific Unions.

Evaluation of Research Activities

The Survey and Planning of Scientific Research Unit of the CSIR was established "to help the decision-makers, by an analysis of the trends in organization and planning of scientific research in the country."[4] Current studies are aimed at achieving five objectives:

(1) Studies on expenditure on scientific research in India as a whole.
(2) Sector-wise study of scientific research to cover national laboratories, universities, industrial laboratories, government laboratories, and other institutions.
(3) Studies of different aspects of scientific activities like the role of scientific socieities, training scientists abroad, and the commitments of scientists to science.
(4) Research trends to determine areas of neglect or over-emphasis.
(5) Special problems of planning and organization of scientific research.

> "The main objective of the studies that are underway is to have an overall picture of scientific research and its development. The analysis of data now being collected will, it is hoped, help the scientists to understand the efficiency with which research is being organized in India and the direction it is taking. Once the basic picture is known, more abstract problems will be taken up to throw light on the problems of planning and organization of research" (A. Rahman).[5]

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IV. SOME RELATIONSHIPS IN THE EVALUATION CRITERIA PATTERNS MATRIX

IV.1 *Collection and Classification of Propositions*

As mentioned at the outset, the intention of this thesis is to continue the analysis of strategies and patterns initiated in the long range study and at the same time to examine basic problem areas noted in the literature on the development and operation of R & D capabilities in developing countries. To the extent that this has been done successfully in the preceding chapters, many basic questions should have been raised and some of the major relationships in the infrastructure pointed out.

To summarize and further define these relationships it is essential to develop a set of propositions for further investigation. Primarily, the term proposition refers to a statement which relates a dependent variable to an independent variable. Herbert Simon in Organizations,[1] notes that in this type of proposition, the variables can: (1) either assume a range of values or, (2) one or more of the variables are dichotomous or unordered discrete values. For example,

> "The economic development of a nation (dependent variable) depends on its scientific growth (independent variable)."

The term proposition is not restricted to this form, i.e., analogous to a mathematical function. Statements which Simon refers to as anatomical include a "qualitative descriptive generalization,"[2] i.e.,

> "The organization of the more efficient research staff has a pyramidal form, where a base of a technical staff supports a better skilled technical personnel with an always decreasing number of persons."

Finally, propositions are included which assert that a particular organizational structure or process performs a particular function, i.e.,

> "Government managerial arrangements are (usually) more suited for tackling specific national problems than those of the traditional university."

One of the first steps to obtaining such a set of propositions is an extensive collection of such selected statements obtained by an examination of the sources of information. However, note that these statements as they stand are not operationalized, in fact they are not always in propositional form. Obviously, the source material such as policy statements and normative monographs were not written with the notion of stating propositions and variables in operational form. Thus, the statements collected should be considered as a collection of potential propositions. The sources of greatest interest were those monographs and articles written by scientists and administrators working in scientific organizations in developing countries. These individuals were not ranked according to professional or organizational status, as this would probably limit the variety of variables and types of relations discussed. A second source of interest was the collection of country policy statements made by leaders of the national scientific bodies. These statements tended to be more formal and more likely to contain aspirations than descriptive generalization and functional relationships. In any case, an effort was made to acquire a broad and representative a 'sample' of the literature to establish a basis for forming testable hypotheses. Many of the statements are normative but they contain what may be essential variables. The selection process was admittedly biased by the writer's own interests and ideas of what is important, but some of the criteria used in these statements is indicated below.

(1) Preference was given to statements that were related to the major topics covered in this thesis.
(2) Preference was given to variables that were more widely used, i.e., in several countries and by many individuals.
(3) Preference was given to variables that could be operationalized.
(4) Preference was given to propositions of the functional type. However, most of the statements were qualitative descriptive generalizations, and include many potential propositions.

The statements have been grouped along lines very similar to the objectives listed in section III. The primary distinction is between propositions relating to the utilization of the scientific capability, and those relating to the increase or improvement in scientific capability itself.

Within these broad categories the topics generally follow the topics discussed in outlining the general model in Chapter II. The classifications are somewhat arbitrary and, in cases, overlapping; further clarity can be expected as the study proceeds and concepts are refined.

SELECTED STATEMENTS ON R & D IN DEVELOPING COUNTRIES TO BE USED AS A SOURCE FOR DETERMINING TESTABLE PROPOSITIONS

A. National Goals and Aspirations

1. Cultural and Social Development

A country without scientists and engineers cannot be in the main stream of modern life.[3]

It is only through the scientific approcah and method and the use of scientific knowledge that material and cultural amenities and services can be provided to every member of the community.[4]

Advancement of science is essential for the growth of a welfare state.[5]

2. Economic Development

a. Relationship of R & D to Economic Development

Direct causal bonds exist between the technical progress and the main characteristic sectors of economical activity.[6]

There is no doubt that as an investment on a national scale, scientific research and the application of scientific knowledge are extremely profitable.[7]

This (see preceding statement) is particularly true in less developed areas where it can be a major contributing factor to economic growth and the raising of living standards.[8]

The economic development of a nation depends heavily on its scientific growth.[9]

Science will be chiefly effective through its influence on long term economic plans.[10]

b. Expenditures for R & D

The higher is the economic development of a country, the greater is the percentage of its Gross National Product invested in research.[11]

Since the development of science plays such a significant and steadily growing role as a result of efforts to ensure an abundant supply of both material and cultural goods, it is necessary to plan the appropriation of funds for science so that it will be able to develop at a faster rate than technique the rate of development of which must, in turn, keep ahead of that of the growth of industrial production.[12]

The situation of small countries materially in keeping up with the contemporary level of both science and research is unfavorable because, in order to maintain the desired level of science, they are forced to appropriate for these purposes a higher percentage of their national income than is the case with large countries.[13]

c. Industrial Development

The chief contribution of technological progress on production is the creation of new products and increased productivity.[14]

d. Discovery and Utilization of Indigenous Resources

The pursuit of these scientific and economic studies geared to each country's natural resources and assets constitutes one of the essential bases for the elaboration of a policy and undoubtedly represents one of the surest means of determining the objectives to be attained and indicating the best ways of achieving the desired results.[15]

B. Organization of Scientific Activity

1. Science Policy

Even though science cannot plan discoveries of new phenomena or laws, it is nevertheless possible--as is borne out by practice--to plan the main courses of scientific and research work, the growth and development of individual groups of sciences and the material prerequisites of their development.[16]

The elaboration and extent of a scientific policy and its repercussions on economic development depend on the part played by the State in the machinery of the economy.[17]

Scientific policy at State level and the responsibilities of Governments in the implementation of this policy--however desirable they may henceforward appear in order to ensure maximum development and efficiency--take on different forms.[18]

Out of all the possible forces for interaction of science and society, the only one governments in less developed countries have at their disposal is planned research policy and their own awareness of its nature and importance.[19]

The provision of money is the basic controlling factor in operating a national scientific policy.[20]

2. Dimensions of the Scientific Network

In nations possessing limited resources, it is most essential to their technological advancement that there be centers for the acquisition of measurement technology and standards.[21]

The effective assimilation of the benefits of science and technology in the less developed areas depends upon the availability of at least one center of technical competence in each independent political domain.[22]

This center (see preceding statement) can provide the nucleus from which all of the most essential functions for internal technical development can grow.[23]

The national labroatory offers the optimum merchanism for such development.[24]

The size and set up of the research laboratories depend on the subjects they handle.[25]

The type of national organization of science which is preferable in a given newly independent growing country is an internal matter of this country and its governmental and scientific communities.[26]

It is probably correct to say that modern science cannot be developed in a newly independent country without the assistance of its government.[27]

3. Coordination of Scientific Activity

Government is becoming the central coordinator and the principal decision maker about science in all countries no matter what their social system is.[28]

The practice of science is expensive and must depend more and more on money provided by governments.[29]

The systematic policy of making the community bear 50% of the country's research expenses acts as a powerful stimulus to the whole economy, and has involved the entire nation in a policy of innovation and of large-scale technical progress.[30]

Scientific research is a creative activity and the usual government administrative framework is without the capacity to accomodate it, largely because of the inflexibility it imposes.[31]

4. Promotion of Science

It is of primary importance that a climate of opinion be created in each country for the acceptance of the need for science and new technology and an understanding of the nature of its benefits.[32]

5. International Scientific Cooperation

It is simultaneously necessary to develop and to intensify the most adequate forms of international scientific-technical cooperation in order to make use of the results obtained in other countries.[33]

Continuity in aid is of special importance and the adoption of new research units by similar groups in developed countries is seen as a means of greatly facilitating the transplantation of research techniques.[34]

Foreign aid will play an important part in building the scientific effort of the less developed countries.[35]

6. Documentation

Important advances can often be met by the application of existing knowledge; because of this, scientific libraries particularly in developing areas, have an important role.[36]

7. Scientific Training

a. Need for Scientific Manpower

The important factors which support the rapid scientific and technological progress will be the scope of research and development as well as the number and quality of scientists and engineers.[37]

In a country undergoing rapid development, providing these types of manpower in sufficient numbers to meet the expanding scientific programs of government, the universities and industry, is a limiting factor.[38]

The underdeveloped countries appear to devote to science and technology a smaller part of the resources allocated to higher education than in the advanced countries.[39]

b. Use of Foreign Experts

A developing country can begin to meet its most immediate economical needs by importing scientists from abroad, but it will never be really independent until it has created its own national pool of highly trained scientists and engineers, and its own scientific institutions, acting in the field of natural sciences.[40]

In most cases staff must be trained, and if developing countries insist on nationals with local training, the whole process may be seriously retarded.[41]

c. Training Abroad

The importance given to the different research fields vary greatly in the developed nations in comparison with the importance they have in the emerging nations. Researchers may acquire estimations of the different scientific fields contrasting with the interest and the general program of scientific research in their own countries. (see preceding statement).[42]

d. Training Technical Personnel

The organization of the more efficient research staff has a pyramidal form, where a base of a technical staff supports a better skilled technical personnel with an always decreasing number of persons.[43]

e. Improving the Status of the Scientist

The recognition of the need to train adequate numbers of scientists and provide them with appropriate remuneration and status in the community is a vital prerequisite for the national development of science and scientific research by any country.[44]

This (see preceding statement) requires adequate primary and secondary education and the provision of a climate of knowledge about science as a career which will attract people to it.[45]

8. Locus of R and D Activity

a. University Research

Every independent country sooner or later has to create and develop a national network of universities and institutes of the highest technological education for the preparation of its skilled engineers, agronomists, university professors and secondary teachers.[46]

The main organizational and administrative features of a government scientific organization should be: (a) maximum autonomy and freedom from Civil Service control, (b) administration by scientists, (c) maximum internal decentralization.[47]

Government managerial arrangements are usually more suited for tackling specific national problems than those of the traditional university.[48]

Research can only flourish in a sympathetic environment, and particular attention must be given to creating conditions suitable for research; the administrative structure of a government department is not suited to this kind of activity.[49]

b. Industrial Research

In this respect it is necessary to emphasize the importance of research departments and laboratories in various branches of industry, which are a logical line between scientific research institutes and production departments in factories, without which there can be no practical mechanism for converting scientific achievements into industrial processes and new products.[50]

Only industry doing research by itself is capable of formulating research problems it could confide to other scientific institutes.[51]

c. Agricultural Research

The diffusion of the results of agricultural research take a considerably longer time than in the case of applied industrial research.[52]

d. Government Research

The practice of scientific research at any level has now become so involved and so costly that provision for it can only be made on a satisfactory scale by governments. (In developing countries this is an economic necessity.)[53]

9. Type of R and D Activity

a. Indigenous Research

This (development and efficient utilization of natural resources) can only be ensured by the development of an indigenous science and technology.[54]

Implementation of such plans (see preceding statement) will be the more effective, the greater the knowledge there is of advanced scientific potentialities based both on highly selective importation of technical knowhow from abroad as well as from indigenous research.[55]

Indigenous research groups are needed to interpret and adapt this knowledge (see preceding statement) and extend it to solve local problems.[56]

b. Adaptive Research

There is a continuing need for substantial research facilities for the modification and adaption of discoveries made elsewhere in the world in order to permit the use of local materials and in terms of local environments.[57]

In many developing areas, urgent problems can be attacked by the application of knowledge which already exists as a result of research carried out elsewhere.[58]

10. Portfolio Emphasis

The decision upon the relative place of basic and applied sciences traces the main lines of the national scientific policies.[59]

This (see preceding statement) problem is by itself of vital importance for the development of science in any country.[60]

Its solution (see preceding statement) will determine to some extent the later decisions on a number of derived problems, including the relationship between short and long term programming and the problems related to the institutional pattern of scientific research.[61]

Even if the applied researches seem to be of more immediate utility for life and for economic and social development of a nation, it is necessary to remember that the basic research (that is the research "performed without thought of practical ends") is also indispensable to this development.[62]

11. Implementing R and D Results

Laboratory scale researches do not normally attract entrepreneaurs in a newly developing country.[63]

In the early stages of industrialization firms are not receptive to new ideas on account of the fact that they do not employ scientists and technologists.[64]

Because of the lack in industry of personal interest in innovations originating from an unattached research institute, the latter must give a great deal of attention to getting its results applied, otherwise much of its research work will be wasted.[65]

The second important difficulty is the lack of an effective method of communication of research results to points of application.[66]

IV.2 Generating New Propositions

Besides a survey of the literature, an alternate method of determining propositions is to develop a "proposition generator" using objectives as dependent variables ans strategies, patterns, or general model elements as independent variables as shown below.

Independent Variable	Relationship	Dependent Variable
Strategy	Increases	R & D Objectives
Elements of Strategy	Decreases	
Pattern	Is Necessary For	
Element of Pattern	Is Sufficient For	
Constraint	Is a Cause Of	
Resource	Is a Consequence Of	
	Is Related To	
	Is Not Related To	
	Is a Basis For	
	Is Not a Basis For	

Naturally, every statement generated by such a device will not be meaningful for further study, but many possible new relationships that might be otherwise overlooked can be noted. For instance, using the objective "reduces imports" a number of meaningful statements result, i.e., Strategy 1,2,3. . . .n decreases imports. Continuing in this manner, a set of relationships in the evaluation criteria-patterns (or strategies) matrix can be generated for further study. The limitations on such a mechanistic approcah is that the problem still remains of selecting a few meaningful propositions for further study once a new list of propositions is generated.

In essence it is a matter of individual choice as to what areas are most significant or interesting for further study, but a few lines of inquiry seem basic to an extensive study of R & D in developing countries. To the author, these basic lines of inquiry have already been indicated by the major topics in the general model. These are noted below with an illustrative statement from the preceding classification of potential propositions. Each of these statements can lead to one or more testable propositions:

(1) Science Policy -
"Out of all the possible forces for interaction of science and society, the only one governments in less developed countries have at their disposal is planned research policy."

(2) Research in Relation to Economic Growth -
"The higher is the economic Development of a country, the greater is the percentage of its Gross National Product invested in research."

(3) International Relations in Science -
"Continuity in aid is of special importance and the adoption of new research units by similar groups in developed countries is seen as a means of greatly facilitating the transplantation of research techniques."

(4) Manpower and Training -
"The importance given to the different research fields vary greatly in the developed nations in comparison with the importance they have in the emerging nations. Therefore, researchers may acquire estimations of the different scientific fields contrasting with the interest and the general program of scientific research in their own countries."

(5) Flow of Scientific Information -
"Important advances can often be met by the application of existing knowledge; because of this, scientific libraries particularly in developing areas, have an important role."

(6) Investment in Research -
"As has been pointed out earlier,the provision of money is the basic controlling factor in operating a national science policy."

(7) Portfolio Emphasis -

"Even if the applied researches seem to be of more immediate utility for life and for economic and social development of a nation, it is necessary to remember that the basic research (that is the research 'performed without thought of practical ends') is also indispensable to this development."

V. CONCLUDING REMARKS AND SUGGESTIONS FOR FURTHER STUDY

Few definitive conclusions can be drawn from a thesis of this type which attempts to explore a field of inquiry in terms of a general model, but it has been possible to outline a set of common trends, recurrent problems, and similar objectives. Furthermore, to achieve these objectives a number of strategies have been devised which, although they vary widely in their structure and function, have common characteristics. Finally, various combinations of these strategies give rise to a variety of research patterns in developing countries.

Among the common trends and problems explored in Chapter II, four stood out: the strong orientation of R & D activities towards social and economic objectives; the dominant role played by the national governments; the important role played by international organizations in industry and funding scientific activities; and the almost universal desire for an indigenous scientific capability.

The common problems center on the lack of a scientific tradition and the consequent lack of a scientific infrastructure and a body of trained scientists. This lack of a scientific tradition becomes a barrier to both indigenous and international efforts to increase the scientific capability. These difficulties were explored in many areas such as the lack of scientific policy; the "secondary status" (whether real or imagined) accorded scientists from developing countries in international organizations; the difficulties in training and keeping scientists and technicians; the isolation and lack of status of local scientists; the lack of scientific information and means of implementation; and the inadequate funding available.

The scientific objectives of the developing countries mirror their aspirations to overcome these problems. Also, they indicate many common economic goals such as completing an inventory of national assets, increasing agricultural and industrial outputs and utilization of indigenous resources. These common economic objectives are causing an increased awareness of the need to establish a scientific capability. As a consequence many strategies have been developed to build this capability. These efforts vary widely in terms of money and manpower required to implement them. At the international level, efforts vary from the United Nations Special Fund and the Rockefeller Agricultural Program to the voluntary work of VITA. Similarly, at the national level, efforts in scope from the inclusive CSIR of India or Pakistan to the small scale efforts of the coffee growers in Guatemala. In general there is a progression in these efforts from projects to permanent organizations, from short to long term efforts, from single to multiple sponsorship, and from completely government sponsored research to a mixture with private efforts. One of the most important features of all these strategies is the increased emphasis on cooperative efforts in regard to staffing and funding.

The R & D patterns also show recurrent characteristics. The main emphasis in R & D activities closely parallel the economic development of the countries with emphasis on agriculture in the smaller less developed countries. Gradually, the scientific infrastructures become increasingly complex with specialized institutions as the economies reach the take-off stage. However, there are notable exceptions such as Malaysia, in spite of prosperity due to rubber and tin, has little R & D effort, while Kenya with its membership in the East African Common Services Organization is comparatively more advanced in R & D activities but not economically. Also, some scientific infrastructure such as the Philippines are highly centralized while Mexico's is decentralized.

However, such general relationships still leave much room for variation in field study design. A few suggestions that became evident during the course of preparing this thesis are noted below. One important distinction governing the order of priority in which these and similar topics could be organized for study would be that between measures to build a scientific capability and those designed to utilize it most effectively in achieving its objectives. Although both types of measures are essential in all developing countries, emphasis in the least developed is more usually on the "institution-building" measures. It is this type of measure which is emphasized below. These suggestions are also made with the notion that they can be initiated in an exploratory manner and, if worthwhile, expanded, rather than initiated on a full scale.

(1) <u>Comparative analysis of efforts to build scientific capabilities in the developing countries with a population of less than 5,000,000</u>

Over forty of the developing nations have a population of less than 5,000,000. Many of these countries have expressed a desire to build an indigenous scientific capability. Lessons learned in India, Brazil, Mexico, Nigeria, and other large developing countries are applicable in varying degrees to these very small nations. In many cases, the objectives, resources and constraints, and accumulated experience (or lack of it) of countries with comparable dimensions is more relevant. A comparative analysis using the general model outlined in this thesis can be developed, but refined to include many more variables with emphasis or institution building and training activities. The level of funding, facilities and manpower requirements for R & D in relation to GNP is especially important. It may be that when economic and technical requirements of national development plans are translated into R & D requirements, two or three percent of GNP as in the U.S., U.K., and U.S.S.R., is inadequate to fulfill these plans.

(2) <u>The effects of the size of a nation on the development of its scientific capability</u>

Countries are severely constrained by their size whether measured in economic, geographic, or demographic terms. A study of selected countries ranging from the smallest and progressively including larger countries until Nigeria, Brazil, Pakistan and India are included will emphasize some of the variables which are dependent on size, both as a source of manpower and funds. Increasingly larger countries can realistically plan and develop larger and more diversified industrial sectors and educational facilities which will ultimately be reflected in their research capability. The larger countries should also be studied as entities important in their own right with unique pattern elements which may not be transferable.

(3) <u>A comparative analysis of the scientific institutions established by the former colonial powers in Africa</u>

The European powers, during the course of their colonial activities in Africa, established distinct and differing organizational arrangements for the development of science; today they continue many of these arrangements on a cooperative basis with different degrees of involvement. Inasmuch as these organizations were, by and large, the only long term efforts to establish scientific institutions until very recently, a study of their similarities and differences is of some significance. It is also important to consider different cultural responses of the former colonies as they assume control of these activities.

(4) An analysis of various forms of regional cooperation in scientific organizations

Regional scientific activity in developing countries is not a dominant form of organization. However, it does exist in a variety of institutions such as the East African Common Services Organization and the Central American Institute for Industrial Technological Investigations. Two factors favor the increase of this type of cooperation: (1) the increasing development of co-operation in other spheres especially the establishment of common markets and free trade areas, (2) the increasing cost of scientific activity which is causing even the wealthy nations of Europe to cooperate on large projects. Some questions that would be of interest in such a study would include: What roles do the member nations assume in such an organization? Are these organizations primarily among equals, or is there a wide range of development forcing some members into a leadership role? What inhibits or fosters the growth of these organizations?

(5) A comparative analysis of national science organizations

The central role of the government in initiating and controlling scientific activities to various degrees in the developing countries is producing a wide range of national science organizations. What provisions are made for decision-making on scientific matters at the national level? How are such organizations funded and staffed? What are their essential functions? What channels of communication exist between the scientists and the political, military, and business leaders? What machinery is available for relating economic development plans to the planning of R & D activities? These are some of the questions that would be relevant to this analysis.

(6) A comparative analysis of the organization of R & D and the diffusion of results in commercial crop sectors

Contrasted with subsistence agriculture, the commercial crops of a country provide a relatively advanced state of agricultural development. They often have private support as well as government support of R & D activities. In spite of attempts to industralize in these countries, such commodities as coffee, cotton, tea, jute, sisal, and essential oils will still remain dominant in many of these countries. Some associations maintain laboratories and experimental farms, and an extension service. The R & D process and the diffusion of results as it applies to a smaller but integrated sector of an economy can be readily studied in this "controlled environment."

(7) The determination of criteria used for project selection

A good deal of work has been done on the problem of project selection in the laboratories of developed countries (see survey of this work by Baker and Pound at Northwestern University).[1] The limited funds and scientific capability coupled with the competing demands for their use in developing countries costs the problem in terms somewhat analogous to those facing an industrial firm. However, the criteria used to determine priorities and make these allocations is on a more diverse and diffuse basis. What is the trade-off between research and education? Between basic and applied research? Between industrial and agricultural research? Which industries and which crops get priority? These questions apply at the macro level, it is also necessary to consider selection procedures within a given research institute in industry or government.

(8) U.S. firms as agents of technological changes in developing countries

Primarily, this study would include the flow of technological information through licensing agreements, patents, and branch operations. It could also be extended on an international basis to include companies from Western Europe and Japan.

(9) Information requirements of scientists in developing countries

The conditions of relative isolation; the greater need; in many cases, to function as a generalist operating in several scientific disciplines; and the emphasis on adaptive and applied research using the resources of scientifically advanced countries results in a different set of information requirements for scientists. It is an important point of inquiry to discover what these requirements are and how they can be met (or not met).

(10) Changing career aspirations of potential scientists studying in the United States and Europe

Many students sent by developing countries to scientifically advanced nations change their career aspirations during the course of their studies. Their initial course of study and aspirations may have been closely identified with the needs of their own country. Later with wider horizons, they may change career aspirations and study plans; they often migrate to better employment opportunities. Which countries experience the highest exodus of students in the sciences and what are the causal factors?

(11) Comparative study of the status of scientists in development countries

Some countries have accorded scientists a higher status than others, even establishing what amounts to a civil service to assure career recognition and advancement. What is the professional status of the scientist in relation to legal and administrative careers? Is a new elite being established composed of scientists and technicians, or are they subordinated to or "unrecognized" by an established hierarchy? How is status related to patterns of migration?

(12) Comparative analysis of causes, rate and direction of migration of scientists from developing countries

The flow of scientists from developing countries reaches significant proportions in several countries. What type scientists migrate from what types of countries? How is this exodus related to the rate of economic and scientific development in these countries? Can this migration (or lack of it) of scientists be related to factors such as participation in formulating science policy and freedom to select projects.

To some extent, all of these studies focus on the problem of finding out which of the developing countries are establishing the nucleus of a scientific community and under what conditions, and which ones are receptive to technological change. This suggests a series of studies in social change and economic development, or comparative intersocial study. In the broadest context, this is true, but primary emphasis is on the structure and function of the R & D organizations in developing countries and their related problems.

APPENDICIES

APPENDIX A

NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS 60201

DEPARTMENT OF INDUSTRIAL ENGINEERING
AND MANAGEMENT SCIENCES

THE TECHNOLOGICAL INSTITUTE

Dear Sir:

Currently we are engaged in a study of the organization of applied research in developing countries. An abstract of this study, which so far has covered Latin America and South and South East Asia, is enclosed. We are now going to extend this study to the nations of the Middle East in order to include a different set of conditions as well as to study an important developing area.

The general objective of our project is to describe the means used by developing countries for establishing and maintaining an applied research capability, and to study the methods of planning and organizing applied research that have proven to be most effective in countries of limited scientific, engineering and economic resources.

At this point we are primarily concerned with actual, existing Research and Development capabilities and would be interested in learning something about facilities that exist for scientific research work in a research institute such as yours. The enclosed questionnaire indicates the specific information we are seeking. We would appreciate your cooperation in filling it out. Even partial information would be helpful. We would also like to receive any of your recent publications such as annual reports.

Your cooperation with our project will be greatly appreciated.

Sincerely,

Albert H. Rubenstein
Professor

AHR:ms
Enc. (2)

____
Name of Organization

1. YEAR FOUNDED: ______________

2. DISTRIBUTION OF ACTIVITIES (Show approximate % of technical personnel that work in the following areas)
   a) Fundamental Research ______________%
   b) Applied Research ______________%
   c) Development ______________%

3. AREA OF RESEARCH (Check areas in which work has been done and specify others in the empty spaces)

   a) Agriculture

________Rice	________Tobacco	______Rubber	_____...........
________Corn	________Tea	______Coffee	_____...........
________Jute	________Wheat	______.........	_____...........

   b) Minerals

________Oil	________Aluminum	______.........	_____...........
________Iron	________Copper	______.........	_____...........
________Tim	________Coal	______.........	_____...........

   c) Industry

________Consumer Products	______.......................
________Durable Products	______.......................
________Basic Processes	______.......................

4. PERSONNEL (Specify approximate number of persons in each category)
   a) Research Scientists ________
   Engineers ________
   Technicians ________
   b) Others (Clerical and Administrative) -----------

5. FINANCED BY:

   ________Government
   ________Industry
   ________University
   ________Others (please indicate)

6. CLIENTELE (Indicate for whom work has been done)

   ________Government
   ________Industry
   ________University
   ________Others

7. INFORMATION PROVIDED BY: ______________________ ____________
Name Date

____
Title

NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS 60201

DEPARTMENT OF INDUSTRIAL ENGINEERING
AND MANAGEMENT SCIENCES

THE TECHNOLOGICAL INSTITUTE

Cher Monsieur:

Nous sommes actuellement engagés dans une étude de l'organisation de la recherche appliquée dans les pays en dévelopment. Un résumé de ce travail, qui a couvert jusqui'ici l'Amérique Latine et l'Asie du Sud et du Sud-Est, est donné ci-joint. Nous allons l'étendre aux nations d'Afrique, afin d'englober un ensemble de conditions différentes tout en étudiant une importante région en développement.

L'objectif général de notre projet est de décrire les moyens utilisés par les pays en développement dans la création et le maintien d'une capacité de recherche appliquée, et d'étudier les méthodes de planification et d'organisation d'une telle recherche qui se sont avérées les plus efficaces dans des pays de ressources limitées dans les domaines scientifique, technique et économique.

Dans l'immédiat notre attention s'attache principalement aux capacités de Recherche et de Développement dejà en existence, et nous serions désireux d'apprendre quelles sont les facilités qui existent dans un Institut de Recherche Scientifique comme le votre. Le questionnaire ci-joint indique de manière plus précise quelle information nous recherchons. Nous apprécierions l'aide que vous nous apporteriez en acceptant de le remplir. Une information meme partielle serait utile. Nous amerions aussi avoir communication des certaines de vos publications récentes, telles que des rapports annuels.

Votre collaboration à ce projet sera grandement appreciée. Nous vous prions d'agréer, Monsieur, l'assurance de nos sentiments distingués.

Je suis,

Albert H. Rubenstein
Professeur

AHR:ms

____
(Nome de l'Organisation)

1. ANNEE DE FOUNDATION: ______________

2. REPARTITION DES ACTIVITIES (Indiquez le pourcentage approximatif du personnel technique qui travaille dans les domaines suivants):

   a) Recherche Fondamentale ____________________
   b) Recherche Appliquée ______________________
   c) Développement ______________________

3. DOMAINE DE RECHERCHE (Marquez d'une croix les domaines dans lesquels un travail a été fait et indiquez les autres sur les lignes laissées en blanc)

   a) Agriculture

_____Riz	_____Tabac	_____Caoutchouc	_____..........
_____Mais	_____Thé	_____Café	_____..........
_____Jute	_____Blé	_____..........	_____..........

   b) Ressources Minérales

_____Petrole	_____Aluminum	_____..........	_____..........
_____Fer	_____Cuivre	_____..........	_____..........
_____Etain	_____Charbon	_____..........	_____.........

   c) Industrie

_____Produits de consommation	_____.............................
_____Produits durables	_____.............................
_____Transformations de base	_____............................

4. PERSONNEL (Indiquez approximativement le nombre de personnes dans chaque catégorie).

   a) Recherche Chercheurs _________
   Ingénieurs _________
   Techniciens _________
   b) Autres (personnel administratif) _____________

5. SOURCE DE FINANCEMENT

   _____ Gouvernement
   _____ Industrie
   _____ Université
   _____ Autres (Indiquez SVP)

6. CLIENTELE (Indiquez pour qui le travail a été effectué).

   _____ Gouvernement
   _____ Industrie
   _____ Université
   _____ Autres

7. INFORMATION FOURNIE PAR: ______________________ ____________

   Nom date

   ____

   Titre

APPENDIX B

Source List of National Scientific Objectives

A. National Goals and Aspirations

1. Cultural and Social Development

To apply (Scientific) achievements for the social and economic and cultural development of the nation.[1]

To stimulate and promote the development of scientific and technological research so as to improve human well-being and to provide for the needs of national culture economy and security.[2]

Utilize scientific knowledge as an effective instrument for promotion of national progress.[3]

The peaceful application of atomic energy to the health, welfare and security of the people of the nation.[4]

To derive the greatest benefit from the activities of research for the economic and social welfare of its people.[5]

Stimulate and guide scientific, engineering and technological efforts towards filling the basic and immediate needs of the people.[6]

The attainment of a high level of living conditions for the people.[7]

To advance and promote in the widest sense of the word, efforts and activities in the field of science serving the interest of peace and mankind in general.[8]

To secure for the people of the country all the benefits that accrue from the acquisition and application of scientific knowledge.[9]

2. Economic Development

a. Orient Research to Economic Development

To develop research related to the national development.[10]

Has launched out on an immense effort to develop the scientific research facilities that are now recognized as vital to the economic progress of the country.[11]

Increase the rate of technological progress.[12]

Carry out and stimulate research in all fields while emphasizing research in a field of production within the framework of ________ National Development.[13]

This 5-year Science and Technology Development Program is based on the recognition of the role of science in shaping nations and in building up a dynamic base for economic and social progress.[14]

b. Discover and Inventory National Assets.

Speed up scientific explorations to increase as quickly as possible our basic knowledge concerning especially, the biological and mineral resources of the country.[15]

Is still a virgin soil, which needs to be thoroughly explored for all materials to establish their availability in quantitative terms.[16]

Setting up research laboratories for the study of _________ resources for the benefit of the economic development of the country.[17]

The Council for Science of _______ which functions as the central research organization will also undertake its own long-range researches aimed at the disclosure of __________ national wealth.[18]

Recognition of the need for studies and research on natural resources and the coordination of the activities of the bodies responsible for them.[19]

c. Increase Industrial Development

The establishment of development and assistance to special institutions or departments of existing institutions for scientific study of problems affecting particular industries and trades.[20]

Development of agricultural and primary manufacturing industries, food and nutrition research.[21]

To utilize and exploit for purposes of experiment or otherwise any discovery or invention likely to be of use to ______ industries.[22]

The utilization of results of the research conducted under the auspices of the Council towards the development of industries in the country.[23]

Research directed toward processing the waste products in agriculture and industry to develop consumer goods and export commodities.[24]

d. Improve Agriculture

Increase production of staple crops.[25]

e. Build Infrastructure of Economy

Closer coordination between industry and agriculture.[26]

Improvement in transportation and communications.[27]

f. Improve Balance of Trade

Many mineral raw materials that the country is importing could be replaced through an adequate research of products of our own land.[28]

Researches directed at upgrading and expanding the nation's export products.[29]

Research directed at increasing the utilization of national resources to produce substitutes for import.[30]

g. Utilize Indigenous Resources

Better exploitation and conservation of our vast fishery, forest and mineral resources.[31]

The development of industrial processes to exploit the vegetable and mineral wealth of a country.[32]

Establishment of research institutions in various parts of the country for undertaking scientific researches in both pure and applied fields which have a bearing on the utilization of the indigenous raw material resources of the country, and also on problems faced by its nascent industries.[33]

To initiate, promote and guide scientific and industrial research primarily directed towards the utilization of indigenous raw materials.[34]

Establishing special research institutes to promote the development of national resources.[35]

The Council was created to promote efficiency and economy in advanced research, on problems which are common to _______, in the renewable national resources of crops and livestock, forests and water systems, wildlife and fisheries.[36]

B. National Scientific Goals

1. Make Scientific Contributions

Break new ground and make worthwhile contributions to the international pool of scientific knowledge.[37]

2. Formulate Science Policy

To formulate national policies on scientific research and pursue specific scientific research at the request of the government.[38]

The promotion, guidance and coordination of scientific and industrial research including the institution and financing of specific research.[39]

Policy of the stateto promote scientific and technological research and development, foster invention and utilize scientific knowledge as an effective instrument for the promotion of national progress.[40]

Recognition of the need to establish at the highest level a body that will be responsible for the elaboration of the national scientific policy and the coordination of research activities. (The structure of such bodies will vary from country to country according to the prevailing structures and conditions in each.)[41]

Survey the scientific, engineering and technical resources of the country and formulate a comprehensive program for the development and maximum utilization of such resources in the solution of the country's problems.[42]

3. Determine Portfolio Emphasis

Our short-term needs require that emphasis be laid on applied research and development projects.[43]

Mankind's endless effort to fill the gaps of knowledge can and must be carried forth by the investigations of local phenomena; ecological, geological, biological, human, etc., as well as of more universal subjects such as the atom.[44]

Planning and execution of projects concerning a long range developmental of science.[45]

Encourage study in the pure and fundamental sciences.[46]

Our short-term needs require, that emphasis be laid on adaptation of foreign know-how that could be improved or modified to suit local conditions and utilize native raw materials and agricultural wastes into quality marketable products.[47]

Recognition of the need to establish a proper balance between fundamental and applied research. The African countries are aware of the importance of fundamental research and oriented research, knowing that their development is indispensable to progress in applied research and that they constitute the base of the pyramid of research activities.[48]

4. Increase International Cooperation

To cooperate with otherinstrumentalities, whether government or private, in matters affecting applied scientific research, and the application of the results of such research.[49]

To make contact and to promote cooperation with research institutes and research workers abroad.[50]

Cooperating with foreign experts visiting or corresponding with the office.[51]

Establish contacts with foreign and international institutions through the excahnge of publications. It also maintains close relations with UNESCO.[53]

Engaged itself in research, as well as taking an active part in promoting scientific cooperation in _____ with foreign countries.[54]

Establish contact and supervise coordination in research matters both within and without ________.[55]

Recognition of the need for scientific collaboration, at both the regional and the continental levels, in order to solve common problems.[56]

To promote international scientific activities and cooperation.[57]

5. Collection and Dissemination of Information

To collect and disseminate scientific and technical information.[58]

Publishing, distributing and exchanging information with other institutions of national and international status.[59]

To disseminate the results of scientific and technological research and to encourage their practical application.[60]

To develop scientific publication.[61]

To develop scientific information.[62]

The collection and dissemination of information in regard not only to research but also to industrial matters generally.[63]

6. Funding

a. Establish Research Funds

To establish funds and make grants for education and research.[64]

National Council on Scientific Development was created for the exclusive purpose of supporting science development on a sustained basis through planning the use and distribution of a special fund which the government puts aside for the specific objective of science development.[65]

The council thus aims to attract staff and funds from overseas for work which is rendered urgent by the growth rate of populations and the need for further development in ___________.[66]

Recognition of the need to include in all national budgets a special chapter for scientific and technical research.[67]

b. Allocate Fellowships and Grants

Offer fellowships to individuals and grants for research projects or programmes of research institutions.[68]

For the establishment of Research Grants, to be granted to the faculty members of the universities and colleges, research scholars of the research institutions and students of the graduate schools of the universities, with a view to promoting full time research work.[69]

Manage the allocation of research grants to various research institutions throughout the nation.[70]

The scope of aids and grants from the long-range Science Development Fund shall be temporarily concentrated on the natural sciences, the basic sciences of medicine, the basic sciences of engineering, the humanities and the social sciences. The allocations to the natural sciences, basic medical sciences and basic engineering sciences shall not be less than 80% of the total amount.[71]

Make awards to research workers.[72]

7. Organization of Scientific Activity

a. Provide Organizational Network

Strengthen and improve the organizational network needed for the implementation of the national science policy.[73]

To establish and to operate research institutes, experimental centers, laboratories, experimental stations, libraries, national reference collections, museums, and other facilities connected with applied scientific research.[74]

Recognition by those governments of the need to establish scientific and industrial research programs, both short term and long term.[75]

c. Promote Scientific Activity

Has taken an active interest in the promotion of science education regionally in _______, and this in turn serves as a stimulus to her own development in the sciences.[76]

To promote and encourage research of the Government and of private concern.[77]

Promote science consciousness.[78]

Promote social science research.[79]

Encourage and facilitate the active participation of domestic and foreign secotrs in furnishing financial, technical and other forms of assistance for scientific and technological activities.[80]

To promote and support research projects and studies that it considers necessary for the advancement of science, the development of the national economy, and any other reasons of collective interest.[81]

To encourage by appropriate means the development of research in private industry.[82]

To forster, promote, and sustain by all appropriate means, the cultivation of science, and scientific research in all aspects--pure, applied and educational.[83]

To promote coordinate, and orient research in fields of pure and applied science.[84]

To promote and coordinate scientific activities.[85]

The state shall promote scientific and technological research and development and foster inventions.[86]

Recognition by the governments of their responsibility for the organization of scientific research and for the encouragement of research by creating an atmosphere favorable to it.[87]

8. Facility Development

a. Improve Scientific Educational Facilities

For the improvement and strengthening of the equipment for science research in the research institute and universities principally in those which have had a fairly good foundation.[88]

Strengthen the educational system of the country so that the same will provide a steady source of competent scientific and technological manpower.[89]

To bring about improvement of scientific facilities and capabilities ____________ Universities.[90]

b. Provide Scientific Facilities

Create new laboratories according to the needs of the state.[91]

The establishment, maintenance and management of laboratories, workshops, institutes and organizations to further scientific and industrial research.[92]

Expansion of well-equipped laboratories with the aid from government, foreign countries and a large number of industrial companies.[93]

Another urgent task is the establishment of facilities for instrument repair and calibration.[94]

To provide a central service for making scientific tests and measurements of all kinds.[95]

Initiate and bring about the establishment of standards, quality control measures and documentation facilities.[96]

To create and support research institutes.[97]

9. Education and Training

a. Provide and Improve Scientific Careers

Upgrade tne careers of the scientific investigators.[98]

Furnish incentives to private and individual initiative in scientific work, as fundamental basis for the advancement of science.[99]

Encourage individual initiative for the acquisition and dissemination of knowledge and the discovery of new knowledge, in an academic freedom.[100]

Insure that creative talent of men and women is encouraged and finds full scope in scientific activity.[101]

While scientific manpower requirements must be thoroughly investigated, attention needs to be directed towards the welfare of the scientific-academic community as whole, and the professional requirements of its members.[102]

To recognize the discovery of new knowledge in an atmosphere of academic freedom.[103]

Recognition by scientists of their responsibilities toward their own countries. Respect for academic freedom and the right to a free choice of methods and techniques are vitally important to the activities of research workers who, however, in choosing their subjects of research, must keep in mind the needs of their respective countries.[104]

Calculated effort, is to create more opportunities, and specific career positions at the services of as many ______ scientists as possible among those now residing in __________.[105]

b. Provide Scientific Training

Aid universities in improving or establishing scientific teaching and research facilities.[106]

It will arrange training courses for research workers, seminars and refresher courses for researchers; lectures on topics useful for research, technical conferences for the purposes of propagating knowledge.[107]

The long range science development plan makes provision for attracting and keeping advanced teaching and research scientists.[108]

Development of a long-range technical manpower training program.[109]

Measures directed to develop scientific and technological manpower.[110]

To develop a program for the effective training and utilization of scientific and technological manpower.[111]

To insure an adequate supply, within, the country, of research scientists of highest quality.[112]

To train scientific research workers.[113]

Training of researchers, and later on, simultaneously, training of teachers and researchers.[114]

Developing a cadre of trained scientists and engineers well versed in modern concepts and materials.[115]

Special attention to the problem of developing its technical manpower.[116]

The development of research manpower.[117]

Training of technicians capable to fulfill the needs of the industry.[118]

To encourage and initiate, with all possible speed, programs for the training of scientists and technical personnel, on a scale adequate to fulfill the country's need in science and education, agriculture, and industry and defense.[119]

Recognition of the need to train a sufficient number of research personnel rapidly as possible, and recognition of the essential role of the universities in this regard.[120]

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CHAPTER V.

1. N. R. Baker and W. H. Pound, "R & D Project Selection: Where we Stand," IEEE Transactions on Engineering Management (Vol. EM-11; No. 4, December 1964; New York: Institute of Electrical and Electronic Engineers, 1965).

APPENDIX B

Note: In the following footnotes, "The Canberra Conference" refers to the Third Regional Meeting of Representatives of National Scientific Research Organizations of the South and South East Asia Regions, Canberra, Australia, February 17, 1964.

1. M. Makagiansar, *The Organization of Scientific Research in Indonesia and Significant Developments and Trends Since 1960*, prepared for the Canberra Conference.

2. Mario B. Pantin, *A Study of the Role of Scientific Research in the Growth and Development of the Latin American Countries* (unpublished Master's Thesis, Industrial Engineering and Management Science, Northwestern University, 1963), p. 25.

3. Pakorn Adubhan, *A Study of the Role of Scientific Research in the Industrial Development of Selected South and Southeast Asia Countries* (unpublished Master's Thesis, Industrial Engineering and Management Science, Northwestern University, 1964), p. 38.

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